Designing Immersion in Art and Culture

INSIGHTS FROM ARTCAST4D PROJECT

Edited by
Davide Spallazzo and Mauro Ceconello

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Introduction

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In the rapidly evolving landscape of digital innovation, *Designing Immersion in Art and Culture* offers a comprehensive exploration of how immersive technologies are reshaping artistic and cultural experiences. This book examines the multifaceted dimensions of immersion, tracing its evolution from foundational definitions to practical applications in public spaces, historical contexts, and future trajectories. By integrating insights from diverse disciplines and case studies, it provides a holistic framework for understanding the profound impact of these technologies.

Immersive technologies, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), collectively recognized as Extended Reality (XR), are revolutionizing how we perceive and interact with art and culture similar to the transformation from pictures to movies with the Frères Lumiere back in the 1895's, it is the 3D video transformation to immersion (3D plus interaction equal to 4D) on the digital level today. These technologies create environments where the boundaries between the real and the virtual blur, offering users deeply engaging and transformative experiences. *Designing Immersion in Art* *and Culture* delves into the intricacies of these experiences, exploring how sensory stimulation, cognitive and emotional engagement, and the sense of presence contribute to a compelling immersive journey.

Chapter 1 sets the stage by presenting a systematic literature review that rigorously defines immersion and its constitutive elements. Spanning nearly a decade of research, this analysis identifies six pivotal keys of immersion: Presence, Cognitive and Emotional Engagement, Sensory Involvement, Embodiment, and Isolation. These elements form the foundation of an immersive experience, highlighting the essential role of technology in creating an engaging sensory and emotional journey for users. By examining the intricate interplay between technological mediation and user experience, this chapter provides a nuanced understanding of immersion's core components.

Chapter 2 transitions from theoretical foundations to practical implementations, focusing on the challenges and innovations in creating immersive experiences in open public spaces. Unlike controlled environments such as head-mounted displays or 360-degree video rooms, public spaces like squares and shopping malls present unique challenges. Through the lens of ongoing installations like *Ariadne's fibres* in Paris, this chapter explores how immersion can captivate unprepared passers-by, transforming everyday environments into dynamic, interactive experiences. The discussion highlights the environmental and technical challenges inherent in deploying such technology-heavy installations in public domains, emphasizing the need for sustainability and adaptability in the face of diverse and unpredictable audience interactions.

Chapter 3 offers a historical perspective, tracing the evolution of immersive technologies over time. From early explorations by pioneers like Ivan Sutherland and Morton Helig to the popularization of Virtual Reality through seminal films such as *The Matrix* and *The Lawnmower Man*, this chapter provides a rich narrative of how these technologies have transitioned from speculative fiction to practical application. It delves into the contributions of visionaries like Myron Kruger, Jaron Lanier, and Thomas Zimmerman, highlighting key developments and the persistent dream of the Metaverse. The chapter underscores how technological advancements and increased investment have gradually overcome earlier limitations, bringing us closer to realizing these immersive visions.

Chapter 4 shifts focus to the practical applications of immersive technologies through a curated collection of diverse case studies. As part of the *ARTCAST 4D* European-funded project, experts from various fields compiled approximately 50 case studies, each illustrating unique applications of immersive technologies within artistic and cultural contexts. These case studies span different geographical and thematic landscapes, offering a panoramic view of how immersive technologies are being utilized globally. The structured analysis provides valuable insights into these technologies' creative and cultural applications, demonstrating their impact and potential to transform how we engage with art and culture.

Chapter 5 delves into the design processes behind creating immersive experiences in the cultural and artistic domains. Through semi-structured interviews with professionals involved in notable projects, this chapter reveals the collaborative, iterative nature of designing immersive experiences. It underscores the alignment of these processes with Design Thinking principles, highlighting the importance of multidisciplinary collaboration and iterative experimentation. The chapter provides a comprehensive overview of the complexities and challenges inherent in creating impactful immersive experiences by mapping the design phases, involved actors, and utilised technologies.

Chapter 6 presents a holistic framework for analyzing immersive experiences, emphasizing the dual nature of these as both technological and cultural experiences. This chapter argues for a dual focus on technological interaction and cultural content, recognizing that the embedded content within immersive experiences assumes cultural significance and shapes feelings, perceptions, values, and identities. By integrating empirical data on user behavior and preferences, it provides a nuanced understanding of how users engage with and perceive immersive technologies. The chapter highlights the transformative power of immersive experiences and offers valuable insights for designers and practitioners aiming to create culturally resonant and impactful experiences.

Chapter 7 concludes the exploration by looking ahead, using participatory foresight activities to depict future perspectives on immersive experiences. This chapter outlines potential future scenarios, emphasizing seamless technology integration, personalized experiences, and the essential role of multidisciplinary collaboration. It identifies current gaps and proposes promising research opportunities, paving the way for transformative advancements in the field. The envisioned scenarios underscore technology's gradual and seamless integration in a blurred reality, highlighting the need for emotional and cognitive engagement, personalized and collective experiences, and the influential role of AI and other rapidly advancing technologies.

Together, these chapters offer a thorough and insightful examination of immersive technologies, providing a rich resource for researchers, practitioners, and anyone interested in the intersection of technology, art, and culture. *Designing Immersion for Art an Culture* maps the current landscape and envisions future possibilities, inspiring a deeper understanding and appreciation of immersive experiences. By bridging the gap between technological innovation and cultural expression, this book contributes to the ongoing dialogue on how immersive technologies can enrich our engagement with art and culture, fostering new forms of creative expression and audience interaction. As immersive technologies continue to evolve, this book serves as a vital guide, illuminating the path forward for integrating these technologies into our society's artistic and cultural fabric.

1. Defining immersion and immersive technologies

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ABSTRACT

This chapter presents findings from a systematic literature review on immersion's evolving definition amidst recent advancements in immersive technologies. Following PRISMA guidelines, 33 studies (2013-2022) from Scopus were analyzed. The results offer a comprehensive conceptualization of immersion and introduce its constituent elements, termed keys of immersion.
The review explores immersion across disciplines, notably in Computer Science and Engineering, focusing on Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) under Extended Reality (XR). It aims to define immersion, examine technology's role, and identify critical elements for immersive experiences. Central to immersion is technology-mediated illusion, emphasizing sensory stimulation and user engagement (cognitive, emotional, physical). The research identifies six keys: Presence (feeling inside the environment), Cognitive and Emotional Engagement, Sensory Involvement (aligning real and virtual environments), Embodiment (active participation), and Isolation (positive detachment).

This review provides a comprehensive overview of immersion's definition amid technological advances. The keys offer insights for researchers, practitioners, and developers in immersive technologies, shaping understanding of immersive experiences.

1.1 Introduction

The emergence of immersive technologies signs a profound shift in the landscape of human-computer interaction. Beginning with tentative experimentations into Virtual Reality (VR) during the 1960s and culminating in the widespread availability of consumer-grade immersive solutions today, the trajectory of immersion has been marked by a path characterised by innovation and rapid advancement.
Once confined to the domains of scientific research laboratories and military training simulations, these technologies have transcended these confines to permeate nearly every aspect of contemporary life. They seamlessly integrate into modern existence, offering transformative experiences ranging from simulated journeys to distant galaxies to the pedagogical training of aspiring medical professionals and even to the virtual attendance of live musical performances from the comfort of one's home. Immersive experiences have become deeply rooted within our digital environment, reshaping our perceptions, engagements, and interactions.

In the rapid expansion of immersive technologies, an imperative for precision in terminology emerges. *Immersion* has become increasingly ubiquitous, yet its precise definition remains elusive. Is immersion merely the sensation of being enveloped within a virtual environment, or does it encompass a broader spectrum of experiences, including a profound sense of presence, agency, and emotional resonance?

The notion of immersion has been a subject of scholarly inquiry within the academic community, with its definition and scope evolving according to various theoretical and disciplinary perspectives. In 1994, Milgram and Kishino introduced the seminal concept of a virtual continuum, positing that immersive experiences span a spectrum from the physical to the virtual realm. This framework laid the foundation for subsequent research and development activities in virtual and Augmented Reality (Milgram & Kishino, 1994). Studies such as the seminal work conducted by Slater and Wilbur (1997) delved into the effects and perceptions of immersion within the context of Virtual Reality technologies. Additionally, Bailenson and Yee (2005) investigated the psychological ramifications of immersive virtual experiences, contributing to a deeper understanding of the applications and potential implications of this transformative technology.

Without a unified understanding of immersion, discussions about immersive art and cultural heritage, among others, risk being ambiguous, hindering the establishment of cohesive frameworks, standards, and best practices. At the heart of this discourse lies the necessity to delineate the nuances of immersion within the context of art and cultural heritage. Is immersion solely dependent on the technological medium employed, or does it extend beyond the digital realm to encompass physical and sensory engagement?

Clarifying the concept of immersion is paramount for stakeholders across diverse fields. Researchers require a solid theoretical foundation to underpin their investigations into the dimensions of immersion. Practitioners seek guidance in designing immersive experiences that resonate with audiences, evoke emotional responses, and convey narratives authentically. Enthusiasts yearn for a deeper appreciation of the transformative potential of immersive technologies, both as channels for artistic expression and as tools for cultural valorisation. By fostering a shared understanding of immersion, stakeholders can deal with the complexities of this rapidly evolving landscape.
This shared lexicon catalyses interdisciplinary collaboration, facilitating dialogue between technologists, artists, cultural heritage professionals, and scholars. Together, they can unlock new avenues for artistic exploration, reimagine traditional modes of cultural representation, and forge deeper connections between individuals and their cultural heritage.

The quest for clarity in defining immersion transcends mere semantics; it lays the foundation for a richer, more meaningful discourse surrounding immersive art and cultural heritage. Accordingly, in this chapter, we report the results of a systematic literature review to provide an updated definition of immersion. The scholarly approach aims to highlight the qualities of a system that should be considered immersive, at least according to scholars. These are intended as operational insights that may guide practitioners involved in the design of such immersive solutions. Moving from these qualities, here named keys for immersion, the chapter further lists those technologies that may be considered enablers of immersive experiences.

1.2 Research approach

To achieve our objective, we conducted a systematic literature review following the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines (Page *et al*., 2021), which provide a standardised methodology for replicable literature reviews.

Our review began with defining search criteria through the creation of two distinct queries, incorporating the terms *immersive*, *immersive technology*, and *definition*. These queries were then executed in the SCOPUS online database, focusing on article titles, abstracts, and keywords. SCOPUS was chosen as the primary research database due to its extensive coverage across multiple scientific disciplines, including humanities and sciences.

The defined queries – (immersion AND definition) and (immersive AND technolog* AND definition) – yielded 636 and 240 papers, respectively. To refine the results, exclusion criteria were applied, including availability of full-text, English language, and publication between 2013 and 2022.

Although the concept of immersion has been prevalent in scientific literature since the 1980s and 1990s, particularly with the emergence of Virtual Reality, our systematic review focused on the past decade to provide a contemporary overview. Our aim was to explore and to clarify how technological advancements have influenced the definition of immersion and its current conceptualisation.

Following the initial exclusion process, 155 papers remained, predominantly from journals related to Computer Science and Engineering. These papers underwent further screening based on title and abstract, eliminating those not pertinent to our research objective. Specifically, studies unrelated to immersive technologies, such as discussions on chemical immersion, were excluded.

Subsequently, 33 papers were carefully reviewed to assess their relevance, during which it became apparent that seminal references in the field needed to be included. To address this, we employed snowball sampling, tracing significant references from the reviewed papers to expand our dataset to 46 studies, spanning various application domains and timeframes.

We conducted two coding cycles to analyse the selected papers using the MaxQDA software. Given the clarity of our research objectives, a preliminary set of categories was established to guide the initial coding cycle (Saldaña, 2009). These categories included *Immersion Definition* and *Immersive Technologies Definition*.

Moreover, after gathering data on the predefined categories, a second round of focused coding was conducted to identify thematic clusters and commonalities (Saldaña, 2009).

Subsequently, affinity maps were created to visualize the prominent topics, aiding discussions on pertinent research topics and guiding researchers towards a holistic definition of immersion. Keywords derived from the analysis were designated as *Keys of Immersion.*

Furthermore, the investigation facilitated the creation of detailed clusters and descriptions of immersive technologies, as outlined in the subsequent sections.

1.3 Immersion: a multifaceted definition

Numerous scholars have contributed to the discourse on immersion, offering diverse perspectives that range from delineating specific characteristics of the phenomenon to observing user behaviours within artificial environments. This section presents the outcomes of the systematic literature review aimed at examining definitions of immersion within artistic and cultural contexts. The review encompasses a spectrum of newly proposed and established definitions, offering an overview highlighting the commonalities observed among various definitions encountered.

The first part synthesises references that conceptualise immersion as the shift of human attention from the physical world to the artificial realm. Building upon this foundation, the second part explores the notion of isolation, which is closely intertwined with and serves as a defining feature of immersion. Moving forward, the third part delves into the fundamental role of the human sensory system in experiencing immersion, elucidating the influence of stimuli from the surrounding artificial environment on human senses.

Finally, the last part examines the varying degrees of user engagement within immersive experiences, underscoring the nuanced levels of involvement contributing to the richness of immersive encounters. This comprehensive exploration aims to provide a holistic understanding of immersion within artistic and cultural domains, shedding light on its multifaceted nature and implications for user experience.

1.3.1 Immersion as a shift of human attention

Upon analysing the selected papers, it becomes apparent that discussions on immersion largely disregard the physical world, placing significant emphasis on the intricate relationship with an artificial dimension. This artificial realm is depicted as essential for crafting immersive environments, projecting the illusion of an alternate reality.

For instance, Slater and Wilbur (1997) define immersion as «the extent to which computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant». Similarly, Zhang (2020) characterises immersion as «the sensory and perceptual experience of being physically located in a non-physical, mediated, or simulated virtual environment».

In this context, the term *inclusive* signifies the extent to which the user's perception and engagement within the immersive environment transcend the confines of the physical world. It captures the degree to which the immersive experience envelops and absorbs the user, creating a sense of detachment from their immediate physical surroundings. As a result, the immersive environment becomes a self-contained reality that overtakes the influence of the external physical environment, fostering a deeper level of engagement and immersion for the user.

Similarly, Sas & O'Hare (2003) underscore the concept of the «shifting of focus of consciousness», whereby users move their attention from the physical environment to an alternative reality.

Murray (1997) describes immersion as «the pleasurable experience of being transported to an elaborately simulated place» and «the sensation of being surrounded by a completely other reality that takes over all of our attention and our whole perceptual apparatus». Additionally, Zhang (2020) highlights the notion of shifting attention by defining immersion as a «transcendental experience of being physically shifted into the virtual space». Zhang further asserts that «immersion in a virtual environment is a technology-mediated illusion that [...] leads to the alignment of one's attentional focus to a synthetic yet perceptually authentic reality». The author also emphasizes the critical role of the senses in redirecting focus from the physical to the artificial world.

The literature review reveals a compelling convergence between the virtual realm and contemporary efforts to define immersion, especially within contexts driven by technological advancements. This convergence indicates a remarkable shift in how immersion is conceptualized, with virtual environments increasingly shaping our understanding of immersive experiences.

While the evolution of immersion definitions is influenced by various factors, such as specific research domains and temporal constraints, the pervasive influence of recently popularised technologies is evident. These technologies, including virtual, augmented, and Mixed Reality, have revolutionised how we perceive and engage with immersive environments. This shift reflects society's growing reliance on digital interfaces and artificial environments to facilitate immersive experiences. Consequently, contemporary definitions of immersion prioritise technological aspects, emphasising the role of digital simulations and sensory stimuli in creating immersive encounters.

1.3.2 Immersion as isolation

Several papers examined in the analysis delve into transitioning attention from the physical realm to the artificial environment within immersive situations. This phenomenon introduces the concept of isolation, wherein individuals find themselves mentally and perceptually detached from their immediate physical surroundings. The concept of isolation within immersive experiences highlights the profound shift in cognitive focus when individuals engage with virtual or simulated environments. As users immerse themselves in these artificial worlds, their attention becomes increasingly directed towards the digital stimuli and sensory inputs presented within the immersive space.

For instance, Lidwell *et al.* (2010) suggest that individuals lose their «awareness of the real world» when immersed in virtual environments. Similarly, Turner *et al.* (2016) establish a connection between the concept of isolation and the technological aspects of immersive systems. They define immersion as «the degree of technologically mediated sensory richness that facilitates isolation or decoupling from the real world». Additionally, Spence *et al.* (2017) conceptualise immersion as encompassing «a range of internally perceived states [...] that focuses the participant's attention to the exclusion of everyday concerns». The authors further explore related concepts such as involvement, multi-level treaty, participant attention, and detachment from the real world. Moreover, the experience of isolation in immersive environments can be characterised by a heightened sense of presence and engagement with the virtual content. As users become absorbed in the immersive experience, they may lose awareness of their physical surroundings, experiencing a state of cognitive and perceptual immersion within the artificial environment.

The sensation of detachment from the physical world, where users fully or partially concentrate on the artificial environment, is linked to the perceived level of immersion. This sense of isolation from tangible surroundings is crucial in amplifying the immersive environment and enhancing the user's feeling of presence within the virtual realm.

1.3.3 Human sensory system and artificial stimuli

While immersion typically revolves around the virtual realm, scholars acknowledge the importance of reconnecting and interacting with the physical world. They highlight the crucial role human sensory and perceptual experiences play in this process. Despite the allure of immersive virtual environments, scholars recognise the inherent value of our physical senses in shaping our understanding and engagement with the world around us, focusing on how humans perceive the artificial environment. Perceiving the immersive environment can be effortlessly experienced. Sweetser and Wyeth's GameFlow model of enjoyment in video games (2005) describes immersion as «a deep but effortless involvement that can often lead to a loss of concern for self, everyday life, and an altered sense of time».

Conversely, a physical sensation linked to perception and verbs like *feeling surrounded*, *enveloped*, and *immersed* are identified in literature as defining features of immersion, despite its occurrence within an artificial environment. Josephine Machon (2013) underscores this notion by defining immersive systems as «systems that generate a three-dimensional image that appears to surround the user».

The verbs *sensing* and *perceiving* appear frequently in the definition of immersion. Murray (1997) captures immersion as «the sensation of being surrounded by a completely other reality», emphasising the sense of being enveloped by an alternate world. Similarly, Biocca and Delanay (1995) delve into the perceptual dimension of immersion, characterizing it as «the degree to which a virtual environment submerges the user's perceptual system». It highlights the immersive experience's ability to deeply engage the user's senses, effectively transporting them into the virtual environment and blurring the boundaries between reality and simulation.

Enveloping stimuli and human perceptions also resonate with Palmer's studies (1995), where immersion is articulated as «the degree to which users of a virtual environment feel engaged, absorbed, and encompassed by the stimuli of the virtual environment».

This further underscores the immersive experience's ability to captivate users and create a profound sense of engagement and absorption within the virtual world.

Other scholars delve into the concept of enhancing human sensory capabilities. Zhang (2020) conceptualises immersion in a virtual environment as a technological system that «engulfs the senses», emphasising the comprehensive nature of sensory engagement within immersive experiences. Similarly, West *et al.* (2015) discuss a «sensory augmentation» phenomenon, particularly in the context of VR and AR technologies, which enhances the interaction between physical reality and digital data. This augmentation amplifies sensory experiences, blurring the boundaries between the physical and virtual worlds.

Human-environment interaction involves multiple senses, as highlighted by Sommer *et al.* (2020), who emphasise that «full immersion addresses all human senses». By engaging all senses, immersive technologies aim to replicate the richness and complexity of real-world experiences, further enhancing the user's sense of presence and immersion within virtual environments.

The sensory environment encountered by users plays a pivotal role in shaping their perception of immersion. Stimuli received through various sensory channels, including visual, auditory, tactile, and others, significantly impact the user's sense of immersion. The quality and fidelity of these sensory inputs, as well as the relative importance of each (such as sight versus stance, sight versus acceleration, etc.), contribute to creating a more immersive and realistic experience. This enhances the overall sense of presence within the virtual environment while isolating users from the physical world, promoting engagement and embodiment. Literature includes case studies exploring the use of sensory stimulation in immersive environments, as evidenced by the work of Pietroni and Antinucci (2010).

While virtual immersion provides captivating experiences, scholars emphasize the importance of incorporating physical sensations and perceptions into immersive encounters. This recognition underscores the need for a balanced approach that integrates both virtual and physical dimensions to create truly immersive experiences.

By acknowledging the interplay between virtual and physical elements, scholars aim to enhance immersive encounters' overall richness and authenticity.

1.3.4 Different levels of engagement and embodiment

The analyzed papers illustrate varying levels of immersion that individuals can experience, depending on how effectively interactions within an immersive environment foster engagement. Spence *et al.* (2017) note that immersive engagement occurs on cognitive, emotional, and physical levels. Slater and colleagues focus on the physical aspect, describing immersion in terms of «sensorimotor contingencies», which Witmer and Singer (1998) define as the «physical actions required within a specific environment to perceive and interact with that environment».

Buttazzoni *et al.* (2022) present the concept of «place immersion», categorized into neuro-spatial, psycho-spatial, and socio-spatial domains. They characterize immersion as an «embodied process of an effortless experience» influenced by «multiple factors including environmental context, cognitive elements, and social interactions». Witmer and Singer (1998) also describe immersion as a response to an environment that «envelops the participant and facilitates interaction with a continuous stream of virtual and haptic stimuli», highlighting the rich, ongoing nature of sensory input typical in immersive settings.

Despite the diverse interpretations encountered, the overarching themes from the literature review converge on the comprehensive nature that defines immersion. The research group has identified engagement as a crucial factor in determining the user's level of focus within the immersive experience, encompassing both cognitive and emotional dimensions. Additionally, embodiment relates to the degree of interactivity experienced by the user within the immersive environment, involving them in various ways.

1.4 Immersion definition and Keys of Immersion

Based on the findings reported in the previous section, this segment offers a synthesized definition that encompasses the traits and characterizing elements recognized by various scholars over the past decade.

Immersion can thus be defined as «the sensory and perceptual experience of being surrounded by an environment perceived by the user as the real and prominent one: this artificial world is able to engage the user cognitively, emotionally, and physically, suspending attention from the concrete world».

This definition highlights the significance of human sensoriality and the stimuli provided by the artificial environment, which overshadow those from the physical realm. The user's attention is fully shifted, leading to complete cognitive, emotional, and physical engagement with the artificial dimension in which they are immersed.

From the literature analysis, as synthesized in the given definition, valuable elements can be extrapolated to identify the distinctive traits of immersion, referred to as Keys of Immersion.

The *Keys of Immersion* encompass recurring elements associated with the concept of immersion and include:

- Presence;
- Engagement:
    - Cognitive level;
    - Emotional level.
- Sensory involvement;
- Embodiment;
- Isolation.

The following section, structured as a glossary, delves deeper into and defines each *Key of Immersion*.

1.5 Keys of Immersion

1.5.1 Presence

Presence is frequently discussed in conjunction with the concept of immersion and is sometimes used synonymously. Slater *et al.* (2009) and Heeter (1992) describe it as the sensation of being within the environment where one is immersed. According to Cummings and Bailenson (2016), increased immersion typically enhances the sense of presence. There is a direct correlation between the perception of presence in a given environment and the level of immersion experienced by the user. When users feel a strong sense of presence, they become deeply absorbed in the artificial world, resulting in heightened immersion.

1.5.2 Engagement

According to O'Brien and Toms (2018), numerous studies have characterized engagement through various attributes, such as media presentation, perceived user control, choice, challenge, feedback, and variety. These attributes collectively highlight the physical, cognitive, and affective aspects of user experiences. They define engagement as «a quality of user experiences with technology that is characterized by challenge, aesthetic and sensory appeal, feedback, novelty, interactivity, perceived control and time, awareness, motivation, interest, and affects». Building on these definitions, a clear relationship emerges between user engagement and perceived immersiveness. Cognitive engagement focuses on the conscious involvement of the user, where active participation and mental concentration enhance the immersive experience. In contrast, emotional engagement emphasizes the subconscious elements of the experience, exploring the user's emotional responses and feelings that may not be immediately evident or consciously recognized.

1.5.3 Sensory involvement

As demonstrated earlier, sensory involvement plays a crucial role in shaping an immersive encounter. According to Naef *et al.* (2022), heightened sensory immersion correlates with enhanced alignment between the real and virtual environments facilitated by advanced technologies. This alignment fosters a stronger sense of presence within the virtual environment. Sensory involvement, integral to immersion, involves the interaction between human sensory faculties and stimuli presented by the artificial environment. It encompasses the engagement of multiple sensory modalities including vision, auditory perception, tactile sensation, and even proprioception, thereby creating a comprehensive and immersive experience for the user.

1.5.4 Embodiment

Embodiment refers to the experience of being enveloped by simulated sensorimotor information in mediated environments, creating a personal sense of undergoing the experience firsthand (Ahn, 2011). It entails a deep engagement on an identity level, focusing more on internal human perception rather than on external interactions with the environment, influenced by the extent of interaction within the experience. Embodiment enables users not just to observe but also to actively participate in and manipulate the virtual environment, thereby significantly enhancing their overall sense of immersion. Through embodied interaction, users gain a sense of agency and control, which strengthens their emotional engagement and cognitive investment in the experience.

1.5.5 Isolation

In the literature, isolation from the physical world is viewed positively in the context of immersive experiences because it facilitates a shift in the user's focus to a virtual environment. Turner *et al.* (2016) describe isolation as a natural outcome of immersion, defining it as «decoupling from the real world». This isolation is essential for reducing distractions and external influences, allowing users to become more mentally and emotionally engaged in the virtual environment. Embracing this isolation enables users to freely explore, interact with, and fully experience the artificial environment, detached from the constraints of the physical world.

1.6 Identifying Immersive Technologies

The term *technology* encompasses the broader technological domains identified and explored as facilitators of immersive experiences, such as Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Extended Reality (XR), projections, lighting systems, and others. In contrast, *tools* specifically refers to the devices and equipment used to practically apply these technologies. This includes Head-Mounted Displays (HMDs), simulators, mobile devices, projectors, and other relevant tools employed to deliver immersive experiences to users.

Various technologies associated with the concept of immersion have been identified in the literature, each offering different levels of immersive capability. These technologies are collectively referred to as immersive technologies. Through systematic literature analysis, it became evident that in the last decade, particularly within the fields of Computer Science and Engineering, Virtual Reality (VR) and Augmented Reality (AR) are prominently recognized as immersive technologies. VR and AR technologies are typically positioned along the Virtual Continuum introduced by Milgram and Kishino (1994), which delineates a spectrum of Mixed Reality (MR) experiences.

Within the Virtual Continuum, Augmented Reality (AR) is situated near the Real Environment, as it overlays virtual objects onto the physical world, while Augmented Virtuality (AV) is closer to the Virtual Environment, integrating physical objects or content into a virtual substrate. According to Lohre *et al.* (2020), Virtual Reality (VR) offers fully virtual worlds, AR enhances real-world interactions with virtual overlays, and Mixed Reality (MR) spans the spectrum between these two extremes. In recent years, AR, VR, and MR have been commonly grouped under the umbrella expression *Extended Reality* (*XR*) *technologies*. Zhang (2020) defines XR as technology encompassing VR, MR, and AR, creating simulated and augmented realities that extend beyond physical boundaries. Furthermore, researchers have explored the concept of the Metaverse in relation to XR technologies, which allows continuous access to online content using XR tools (Pimentel *et al*., 2022). Initially defined by Stephenson (1992) as a realm where human avatars interact with software agents in a 3D space mirroring reality, the Metaverse has evolved. Lee and Kim (2022) provide a comprehensive definition, describing it as a persistent mixed-reality world where people and objects interact synchronously across time and space, utilizing avatars, immersive devices, platforms, and infrastructure.

Building upon these insights into immersive technologies, the following sections present definitions of VR, MR, and AR derived from a systematic review of literature published in the past decade. Additionally, explicit connections to the Keys of Immersion defined in the preceding chapter are highlighted.

1.6.1 Virtual Reality

Jaron Lanier first coined the expression *Virtual Reality* in 1986, which has since evolved with advancements in technology. Various definitions of VR have emerged in the literature, often reflecting aspects associated with the previously identified Keys of Immersion. Presence, engagement, and sensory involvement are among the recurring terms found in these definitions.

Steuer (1992) associates VR with presence and telepresence, describing it as «the sensation of being in an environment generated by natural or mediated means». The Department of Defense (2018) emphasizes presence within virtual environments through the perception of objects. Benoit *et al.* (2015) suggest that VR «can evoke the sensation of physical presence in locations representing real or imagined worlds».

Engagement is highlighted in several studies focusing on interactivity and user experiences in VR environments. Bisson *et al.* (2007) define VR as «a real-time interactive simulation», while McCloy and

Stone (2001) describe it as enabling «real-time interaction with digital databases». Barbosa *et al.* (2019) compare VR to «an immersive individual experience driven by interactive stimuli». Optale *et al.* (2010) connect VR's interactivity with visual, tactile, and kinesthetic perception, and Hsieh *et al.* (2018) explore user interaction through multiple sensory modalities.

Sensory involvement is another concept emphasized by scholars. Sommer *et al.* (2020) note the integration of visual, auditory, and haptic senses in VR applications. According to Merriam-Webster's online dictionary, VR is experienced through sensory stimuli such as sights and sounds. Kilmon *et al.* (2010) and Mantovani *et al.* (2003) describe visual and auditory feedback as pivotal for immersion in VR environments. Lohre *et al.* (2020) link head-mounted displays and controllers to visual, auditory, and haptic feedback. Dos Santos Mendes *et al.* (2012) define VR as a «computer-based technology providing a multisensorial environment».

Regarding the virtual environment itself, scholars highlight that VR is generated from a computer device to create a three-dimensional environment. Schroeder (1996) defines VR as a computer-generated display that enables users to interact within a distinct environment. Glännfjord *et al.* (2017) characterize VR as a computer-generated simulation producing a realistic-looking world, while Levy *et al.* (2016) depict it as an interactive, computer-generated three-dimensional environment. The INACSL Standards Committee (2016) defines VR as a «computer-generated reality» that facilitates auditory and visual stimuli for learners.

In summary, the definitions and perspectives on VR from various scholars underscore its capability to create immersive experiences through sensory engagement, interactive elements, and computer-generated environments. These aspects align closely with the multidimensional nature of immersion as delineated in the literature.

1.6.2 Augmented Reality

The expression *Augmented Reality* was first coined by Caudell and Mizell (1992) and discussed by many scholars over the years. In their study, Ardiny and Khanmirza (2018) analysed the Milgram and Kishino (1994) Virtual Continuum, previously cited, to provide a definition of AR.

Their proposal described it as «an interactive experience in the real-world environment where the computer-generated information and elements are linked to the real world».

The scholars also analysed the production of AR contents as divided into three steps:

1. all physical-world data is collected by various sensors;
2. this information is then analysed, and additional information from different information sources;
3. the gained information is displayed as digital elements.

Analysing the definitions of Augmented Reality selected from the literature analysis, the connection of this digital technology with the real world is stressed out. Parveau and Adda (2018) define AR as technology that superimposes virtual information upon the real world, for example, adding text or images to what the user sees. Lopreiato *et al.* (2016) report the verb «superimpose» as well, talking about AR as a technology connecting synthetic stimuli to real-world objects. For the Department of Defense (2018) of the United States of America, AR overlays digital computer-generated information in natural-world objects or places. Its scope is to enhance user experience. «Overlay» is a word that is also found in the definition of Berryman (2012) that positions AR as between reality and digital information and emphasizes its role in improving the learning process. Azuma *et al.* (2001) define the combination of reality and virtual objects in the natural environment as a property of AR systems. Virtual objects coexist with the natural world in the same space. The combination of virtual elements and concrete world objects/images is an item also reported by Botella *et al.* (2016) and Lohre *et al.* (2020).

Regenbrecht and Shubert (2021) have studied the sense of presence inside the AR contest. Their studies regarded how important is the recognition of the virtual object as a tangible object by the user experiencing AR content. This could be related to Lee's (2004) definition of presence, as a «psychological state in which virtual (para-authentic or artificial) objects are experienced as actual objects in either sensory or nonsensory ways». The analysis of their results showed that both realness and spatial presence contribute to the acceptance of an AR system by users. It is also interesting the way in which they underline different ways of having AR experiences through head-mounted devices, hand-held devices, and projections on real-world objects. The sense of presence is also studied by Marto *et al.* (2020) related to the sensory involvement concept in AR. Indeed, in their study on AR experiences for Cultural Heritage, they define the integration of smell and audio as sensory stimuli enhancement of AR technology. The conclusion of their statistical analysis demonstrates how the involvement of a sensory part inside the AR experience does not directly enhance the sense of presence of users, but it influences the enjoyment of the experience and the acquired knowledge from the cultural visit. In their study, Arghashi and Yuksel (2022) investigated the level of engagement AR technologies bring to the consumer experience for brands strategy. They report other studies confirming that the engagement felt by customers enhances consumer satisfaction (Javornik, 2016; Hilken *et al.*, 2017; Yim *et al.*, 2017; Rauschnabel *et al.*, 2019; Smink *et al.*, 2019; Nikhashemi *et al.*, 2021;). AR leads to great interaction (McLean & Wilson, 2019), immersion, novelty, enjoyment and usefulness (Yim *et al.*, 2017) for consumers experiencing it. Moreover, other fields recognize this enhancement of engagement level. For example, in the application of AR technologies within circular economy activities and information, Katika *et al.* (2022) found a high level of user engagement, while Zuo *et al.* (2022) studied high engagement levels in the learning and gaming fields.

1.6.3 Other technologies and tools for immersive experience

Some technologies are discussed solely within specific application case studies, complicating the retrieval of prior research and literature on these technologies. However, we found it valuable to incorporate them into the chapter to present a broader view of available immersive technologies and tools. Below, concise definitions of each technology are provided.

Head-mounted display (HMD)

HMDs are wearable devices resembling goggles that users wear directly on their heads. These devices project digital or virtual information onto screens that cover the user's normal field of vision (Milgram & Colquhoun, 1999). HMDs can be utilized in both VR and AR technologies: in VR, the content is displayed to the user through lenses inside the visor, creating an immersive virtual environment. In AR, the HMD functions as a transparent lens through which users perceive the real world enhanced with AR projections displayed on the lens itself.

Cave Automatic Virtual Environment (CAVE)

It is described by Manjrekar *et al.* as a completely immersive Virtual Reality setting designed to replicate controlled environments (Manjrekar *et al*., 2014). Typically, a CAVE consists of a cubic room with rear-projection screens on its walls (Muhanna, 2015). Users are immersed within this cubic space and can interact with the virtual content presented. This system was first developed in 1992 by researchers at the Electronic Visualization Laboratory at the University of Illinois (Cruz-Neira *et al*., 1992).

Projections

The technology of projection for immersive installations and experiences holds significant practical implications. Drawing insights from grey literature and examining various technological aspects highlighted in case studies (Maldovan *et al*., 2006), it is observed that projection for immersive environments involves using projectors to display digital audio-visual content onto surfaces or objects within the physical environment. Some studios and artists also employ 3D mapping technology to project video or images onto buildings, specific environments, or three-dimensional geometries, ensuring a precise alignment of audio-visual content with the physical space, even when an audio system is not necessarily integrated.

Video 360°

Li *et al.* (2019) define the 360° video/image, also referred to as panoramic, spherical, or omnidirectional, as a novel multimedia format that delivers an immersive user experience. This content surrounds the viewer, providing a panoramic view distinct from traditional 2D representations, which are limited to flat planar surfaces. Apple Inc.'s QuickTime VR serves as a commercial example, enhancing this approach by transitioning from still images to video clips, initially branded as QT-VR 3.0. The immersive effect is achieved through audio-visual content projected onto a sphere, covering the viewers' entire 360°×180° field of view.

Body tracking tools
As reported by Watada *et al.* (2010), tracking can be broadly defined as estimating an object's trajectory within a scene's image plane. Huang and Huang (2002) further emphasize that visual tracking of human body movement is now a pivotal technology across various domains. Body tracking technology plays a crucial role in immersive environments and installations by capturing and transmitting users' position and movements to the digital/virtual system, thereby enhancing interaction through multiple modalities.

Haptic devices.
According to Sreelakshmi and Subash (2017), haptic technologies are «the science of integrating touch sensation and control into computer-generated applications». Steinbach *et al.* (2019) define haptic devices as mechatronic systems that provide force feedback to users. These devices enable users to perceive the tactile sensation (e.g., velvet) and the physical presence or force of virtual objects (e.g., surgical instruments for operations, manipulation of delicate or soft objects), thereby ensuring enhanced control and interaction through tactile feedback.

Audio systems
Valbom and Marcos (2005) identified sound as a crucial element in establishing atmosphere and emotion. Their research underscores the importance of integrating sound with emerging interaction methods like gesture-based actions and 3D visual content within immersive environments.Significant advancements in this domain include the THX audio specifications, primarily designed for movie theatres and IMAX, alongside holophonic audio systems. According to literature findings, the primary role of immersive audio systems is to synthesize, manipulate, and render sound fields in real-time (Kyriakakis, 1998).

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2. Opening up immersion: creating alternative realities in public spaces

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ABSTRACT

Immersion has nowadays become ubiquitous and can almost be considered a prerequisite for contemporary art, whether it be live performances, installations, or exhibitions. Oftentimes, technology-based immersive experiences are developed for dedicated equipment (such as head-mounted displays or 360° video rooms) where the environment is fully controlled allowing visual and sonic stimuli to be uniquely ruled by the artistic proposal. Despite the technology on offer, the implementation of immersive settings in contingent open spaces (such as public squares or shopping malls) remains a particularly challenging task. Visitors are passers-by with no preparation whatsoever. They have not purchased any entrance tickets. They are not given one.
They have not come to participate in the proposed experience. They usually have no time for it. They have no such intention. This chapter starts with a rationale for alternative realities in open, public spaces and a proposition of the technologies and immersive dimensions that appear most relevant in this context.

The focus of the chapter then lies on the main challenges that arise when designing and implementing installations in such environments. General technological, ecological and psycho-sociological aspects are addressed and discussed along with two current digital, immersive, open-space artworks: *Primary Intimacy of being* and *Ariadne's fibres*.

2.1 Introduction

2.1.1 Why? – A rationale for alternative realities in public spaces

When you are driving down the D5 departmental road in Vitry-sur-Seine, France, and come to the traffic circle of the Libération, Jean Dubuffet's monumental sculpture, *Chaufferie avec cheminée*, soars high into the sky with the author's saying: *Art has to pop up where you least expect it, by surprise* that is, in public spaces, where people pass through to get from one place to another, where they pass by, where they meet, in the open *where no one thinks of it or speaks its name*. Art is then a vehicle for serendipity. It may slow down the flow of cars and capture the passers-by. It may even induce a resonance, according to Hartmut Rosa, along which the relationship between the people and the surrounding world is mutually moved and transformed (Rosa, 2019). Public spaces become forums where, beyond human errands, emotions can be socially shared.

Public spaces are understood here as any place that is open and accessible to everyone, without any ticket or entrance fee, any space that people can freely cross or occupy. They include roads, pavements, squares, and shared nature. They extend to the urban environment, including building facades and everything that falls in the field of view. They can spread into public or private centres like libraries or shopping malls. Public spaces shape our habits and social behaviours. They define our ways of collective life.

When art suddenly appears on the way, it may simply be an obstacle for passers-by to avoid or to acknowledge, a perturbation that may be powerful enough to induce curiosity, to get some attention, and to modify the trajectory originally planned through the given space. Art can be teasing, stimulating, or interesting enough to open a window to other worlds for passers-by, allowing them to escape everyday life without necessarily noticing, without accounting for both the personal and social, the emotional and rational values they are effortlessly harvesting. People will eventually pass by with shifted feelings and thoughts that art only can induce if resonance occurs. Digital immersive technologies are prone to favour energy transfers with the passers-by and thus to induce resonances with them. The energy transfers can easily be sonic, visual, vibrational, or fragrant. The underlying program of a sensing installation can virtually support any interacting – potentially appealing – behaviour of the art installation with humans.

As the human-machine etiquette is not settled yet, it is a field of research for pioneering artists and an engaging playground for early adopters. According to Dai (Dai, 2023), «artists are incentivized to produce work that will stand out and effectively draw interest from a restless follower base». Dai also finds «an inherently playful quality to the application and dissemination of digital art» as «its novelty inspires a childlike approach to engaging with the experimental medium, fueled by a *pioneering spirit* founded in a charming sense of unfamiliarity among all practitioners».

However, programming codes and social codes in collective immersive installations are still new to both creators and experiencers, so the coupling is not necessarily strong on the way, when people pass by. Besides, the field is largely occupied by marketing and advertising with the same supporting technology that the passers-by's attention is already trained to avoid, so the interactions often remain non-resonant. This is where art can come in, triggering resonance, bringing people's presence in the open space, *by surprise*.

2.1.2 What? – Setting and definitions

This chapter looks at the question of how immersive experiences can be created in open, public spaces. The spaces considered are *public* in the sense that they are freely accessible to everyone and *open* in an architectural sense, meaning that people move through these spaces as *passers-by*. Good examples of such open, public spaces are therefore sidewalks, public squares or even shopping malls while places like public libraries or churches do not fall into this category. The archetypical examples of immersive technologies are *head-mounted displays* (HMDs, often also referred to as *VR headsets*) and audio-video installations housed in closed rooms or structures (we will refer to the latter as *closed-space audio visual environments* or *CSAVEs* for short)[1]. Both HMDs and CSAVEs are in principle viable options for open, public environments. For instance, one might simply hand out HMDs with pre-installed Mixed Reality (MR) or Virtual Reality (VR) applications to passers-by in a shopping mall or a city square. Moreover, with the advent of autonomous consumer VR headsets with passthrough functionality – such as the Meta Quest 3 (*Meta Quest 3*, 1BC) and the Apple Vision Pro (Apple, n.d.) – it is conceivable that passers-by will soon be coming to public spaces wearing their own HMDs. Using positioning methods like geo-localization or RFID transponders, one could then propose site-specific MR or VR contents to the wearers when they enter a predefined zone.

Note 1.
Another typical example are CAVEs (short for *Cave automatic virtual environment*) (Cruz-Neira *et al*., 1992), however, such systems are still mostly found in research contexts and laboratory conditions.

On the other hand, CSAVEs can also be set up in public environments as demonstrated by the company Hubblo (Hubblo, 2024). One of the company's specialisations is the deployment of mobile cinema domes which offer spectators movie experiences similar to those in planetariums and which are frequently used for temporary exhibitions in public spaces. An even more immersive example may be the interactive 360° structure *The L∞p* which has recently been exhibited at Les Ateliers des Capucins, a cultural and shopping centre located in the city centre of Brest (Figure 1).

The approaches described above are conceptually straightforward, technically feasible, and have the potential for unique and highly immersive experiences in public spaces. However, they also present important constraints: Firstly, HMD-based experiences require the passer-by to put on or bring special equipment which may not be very accessible, affordable or even desirable for the general public. Secondly, in CSAVEs, visitors enter a box or structure that is effectively sealed off from the light and sound of the surrounding environment, thereby creating an isolated room within the public space. This compromises the aforementioned aspect of *openness*. HMDs also impose a certain degree of isolation since the direct perception of the surrounding people and environment is intercepted and replaced by signals processed in cameras, screens and loudspeakers.

The focus of this chapter will therefore lie on a third approach: the *open-space setup*. Here, the stimuli-producing hardware is either openly installed in the public space (e.g.: TV screens placed in the centre of a public square) or seamlessly integrated in the surrounding architecture (e.g.: TV screens built into a shopfront or video projection onto a wall). Different examples of such installations will be mentioned in section 2, while section 3 will analyse two specific cases.

Figure 1. *The L∞p* by Ikse Maître and des Vues de l'esprit, a 360° immersive and interactive experience at Les Ateliers des Capucins in Brest, France. The photo shows a moment during the interactive experience *The Arrow of time* with visitors.

2.1.3 How? – Immersion dimensions and parameters

Although the terms *immersion* and *immersive* have become ubiquitous in recent years, a precise and universally accepted definition (especially within the academic discourse) is still lacking. Moreover, there are several related concepts that are often mentioned in connection with immersion and sometimes even used synonymously.
In this chapter, we will follow the taxonomy proposed by Nilsson *et al.* (2016) which distinguishes three main dimensions:

1. system immersion: an objective property describing the technological capabilities of a system;
2. narrative immersion: a subjective «response to an unfolding narrative, the diegetic space, or virtual characters»;
3. challenged-based immersion: a subjective «response to challenges demanding use of one's intellect or sensorimotor skills».

HMDs and CSAVEs can deliver a high degree of system immersion, however, they will not be further discussed in this chapter due to the aforementioned constraints in open spaces. Consequently, narrative and challenge-based immersion can be regarded as the most relevant dimensions for the creation of *immersive* realities in open spaces. A central parameter in this context (especially with respect to the latter dimension) is interaction which is why interactive installations will play a prominent role in the following sections.

In a meta-analysis of 83 studies, Cummings and Bailenson looked at different technical parameters of immersive installations and evaluated their relative importance for immersion[2] (Cummings & Bailenson, 2016). They found factors like tracking level, stereoscopy, (image) update rates and field of view to have more impact than variables relating to content fidelity, such as image resolution, image realism, presence/absence of sound or sound spatialization. Intuitively, this can be understood when one admits that immersive experiences require a «willing suspension of disbelief» (Ernst, 2016), i.e. the experiencer must (at least temporarily) accept the *realness* of the proposed virtual contents and look past the fact these contents are artificially generated and presented to them through a technological medium. Following this logic, it is easy to see that a convincing feeling of presence can be induced even with stylized avatars or a slightly pixelated image of abstract objects. On the other hand, if systems suffer from slow update cycles or imprecise tracking, experiencers will be constantly reminded of the involved technology which will make it more difficult for them to block out the artificiality of the proposed experience. A related argument is put forward by Siess *et al.* who, in their report on worldmaking and design of interactive VR environments (Siess *et al.*, 2019), state that perfect realism is neither needed for immersive experiences nor desirable from an artistic standpoint.

While the findings of Cummings and Bailenson mainly provide guidelines for the successful achievement of system immersion, a few conclusions can still be drawn regarding immersive open-space installations: images should be displayed in large formats to provide a wide field of view for the experiencers; interactive installations should ensure precise and reliable input tracking; the installation must run smoothly, lag should be minimised and choppy framerates must be avoided. Finally, it should nonetheless be noted that there can be no single clear-cut recipe and that there are many different

Note 2.
More precisely, they looked at the correlation between immersion (which they define as an objective quality of the technology) and presence (the subjective, psychological feeling of *being there* in a virtual environment).

approaches to achieving a well-working immersive experience in an open space. The following sections will present and discuss several common challenges and mitigation strategies that occur in this context.

2.2 Challenges of creating immersive environments in open, public spaces

2.2.1 Technological challenges

Immersive open-space installations often make use of large screens or video projections to create digital displays that can be placed in passageways, integrated in or projected onto walls or building facades, or even layered over public furniture (Roussou, 1999). Müller *et al.* (2010) distinguish four typical design models in this context:

- poster: a framed, digital display (possibly enhanced with sensing capabilities), installed on walls or vertical surfaces, e.g.: *CityWall*, a large multi-touch screen exhibited in the streets of Helsinki in 2007 (Peltonen *et al*., 2008);
- window: a display representing a portal to a geographically remote or a virtual place, offering a two-way communication channel where experiencers can look inside the window but people or avatars on the remote side can also look back, e.g.: *Hole-in-Space* (Galloway & Rabinowitz, 1980);
- mirror: a display mirroring (aspects of) the real, contingent environment, and typically augmenting or distorting them, e.g.: *Magic Mirrors* (Michelis & Resatsch, 2006), *Primary Intimacy of being* (section 3.1), and *Ariadne's fibres* (section 3.2);
- overlay: a seamless video projection onto a surface or object, usually with the aim of augmenting the contingent environment, e.g.: *AAAquatik* (Berriet, 2019) at *Jeddah Season Festival* (Figure 2).

External light sources and especially sunlight represent a central challenge for such video-based installations as they can drastically affect the visibility of the display. It is therefore generally preferable to place displays indoors or in a permanently shaded area or to opt for a nocturnal installation. Particular care, however, must be taken when designing outdoor installations that are supposed to run both at day and at night. While display luminosity may be insufficient during daytime, very bright screens may elicit luminance discomfort in the dark (Yan *et al*., 2023).

Figure 2.
AAAquatik (2019), a generative and interactive overlay-type installation by Mâa Berriet, Jeddah Season Festival, Saudi Arabia (©Emmanuel Mâa Berriet).

Another related problem may be summarised as *perceivability*, i.e. firstly: can passers-by easily see the display or does it frequently get occluded by objects or other people? And secondly: do passers-by quickly notice the display? In other words, is the display within their field of view and is it physically in their path, slowing them down? In their pioneering study around *The Opinionizer*, Brignull and Rogers recommend displays to be installed at least partially above head height and to choose an installation site that is both close to a continued flow of people and surrounded by sufficient empty space (Brignull & Rogers, 2003). Concerning interactive installations, Lösch *et al.* (2017) found that the addition of extra screens can increase the attractiveness but may also enhance distraction and prevent interaction with the main display.

Beyond video, immersive installations often include sound components to signal or acknowledge an interaction and to generally favour immersion. In busy places, the installation sounds will have to compete with significant levels of background noise. While increasing the volume of the installation audio may be a simple solution, it can quickly cause discomfort among visitors of the installation as well as neighbours and other passers-by. It could deter people from the installation and result in the installation being muted for the sake of local users and passers-by.

A better mitigation strategy might therefore be to enrich the sound composition and use specific sounds that stand out in the specific environment of the installation (e.g. a voice saying *hey!* or the chirping of exotic birds) or in making use of directional speakers such as the *Audio Spotlight* (Pompei, 2019) which can restrict sound to a narrow conical volume, thereby enhancing auditory contrast (a passer-by will only hear the audio when inside the sound cone).

Another challenge specific to *interactive* open-space installations concerns the input channel. Oftentimes cameras with infrared or depth sensors are used to detect people or poses, however, detection accuracy can be compromised by interfering light sources and especially by sunlight. Moreover, detection in public spaces may require the coverage of relatively large distances and big areas which can quickly exceed the maximum range of most depth cameras (typically 5 to 7 m). Outdoor LiDAR systems can represent a solution in this context, offering higher ranges and more resilient signal stability. Moreover, simple webcams are also starting to become a viable alternative as machine learning (ML) algorithms such as *OpenPose* (Cao *et al*., 2018) or *YOLO* (Terven & Cordova-Esparza, 2023) offer real-time multi-person pose estimation from simple RGB images while models like *MiDaS* (Ranftl *et al*., 2019) can compute relative depth maps from single monocular images.

Yet another approach focuses on Mixed Reality experiences that exploit the computing power and built-in features of modern smartphones. Using the GPS and the phone camera, people can augment their immediate environment with projections and virtual objects as in *LIKE BEAUTY IN FLAMES* (Holzer, 2021) or get immersed in *Locative Augmented Reality Games* (Paavilainen *et al*., 2017), offering parallel worlds localised in the street and enhancing social interaction. Mobile devices can also be used as a remote control or input channel for the artwork, as in the case of *ATHsENsE* (Charitos *et al*., 2019) where feelings can be expressed through textual inputs which are displayed by floating polygons.

Finally, immersive installations in public spaces face general technical difficulties: real-time interaction requires fast communication channels (wire, WIFI, etc.) or the use of embedded systems. Moreover, the installation components (displays, video projectors, sensors, loudspeakers, computers etc.) must be mounted and wired in a way that is both unobtrusive[3] and safe *for* the public, but also protected *from* the public and the potential degradation caused by individuals as well as weather conditions.

Note 3.
Unless the technology should be highlighted as part of the installation aesthetic.

2.2.2 Ecological considerations

Immersive installations for public spaces usually require high-performance video projectors or bright screens as well as loudspeakers or other sound devices. Moreover, if the installation is supposed to be interactive, tracking systems such as cameras or sensors must be added and oftentimes modern computers with powerful hardware are needed. All this equipment comes with a significant environmental footprint, arising not only from the operational energy consumption but also importantly from emissions and pollution created during the manufacturing process (Table 1).

Device	PCF [kg CO2eq]	Reference
Laptop computer (Dell Precision 3581)	343 ± 70	(Dell Technologies, 2023a)
Workstation computer (Dell Precision 5860 Tower)	1775 ± 777	(Dell Technologies, 2023b)
Computer monitor, 27 inch (Dell P2721Q Monitor)	581 ± 104	(Dell Technologies, 2020)
LED TV screen, 43 inch (LG 43LW310C)	201	(LG Electronics, 2016)
Video projector, 4000 lm (BenQ LH650)	77	(BenQ, 2023)
Video projector, 4000 lm (BenQ LH730)	134	(BenQ, 2023)

Table 1.
Product carbon footprint (PCF) of selected example devices.

Beyond hardware, the increasing use of ML algorithms (such as neural network models for person or object detection) has to be considered, too. The training of such models can consume large amounts of energy. It is therefore necessary to ensure that the impact of the models used is measured and reduced and that their use is restricted to the strictly necessary (Luccioni *et al.*, 2023). Moreover, new ML techniques often require the use of recent graphics cards to run at an acceptable frame rate. This encourages frequent hardware renewal – an unsustainable and undesirable practice considering the associated environmental damage. Consequently, there are growing concerns regarding the ecological footprint of digital technology and its uses (Gupta *et al.*, 2020), even to the point of talking about «ecocide» when it comes to computing (Comber & Eriksson, 2023). The art world is also concerned about its environmental impacts, as demonstrated, for example, by the French CEPIR project (*Cas d'Étude Pour un Immersif Responsable | CEPIR*, n.d.), which aims to assess the environmental impacts of virtual or Augmented Reality.

One must also consider the environmental damage caused by *waste electrical and electronic equipment* (WEEE or *e-waste*) which in itself justifies extending the life of equipment as much as possible. Indeed, WEEE is extremely poorly collected, worldwide only 17,4% are collected in approved channels (Forti *et al.*, 2020), with the result of some equipment ending up in open dump sites where its components can cause various forms of pollution, including genotoxicity in plants, DNA modifications in certain bacteria and animals, and reproductive problems (Comber & Eriksson, 2023).

When setting up an artistic project that uses digital tools, there are several *ecological best practices* that should be respected, if possible, starting upstream of the project:

- re-use or rehabilitate old machines or second-hand equipment and/or opt for community management and open-source software (Franquesa & Navarro, 2018);
- apply software eco-design principles during application development, where appropriate, respecting the upstream and downstream phases, in particular regarding the final deployment;
- monitor the operational energy consumption and choose a reasonable shutdown and maintenance policy for hardware and software that takes into account both energy consumption and the risk of software-related obsolescence;
- privilege a distribution approach that minimises environmental damages. For example, consider developing source code that

can be easily distributed via a sharing platform and that can be installed on the existing equipment at the exhibition venue (software portability/compatibility).

In general, it will be important to replace the *race for optimization* by a search for artistic devices that are as frugal as possible, thus respecting the concept of planetary limits applied to the digital (Pargman *et al*., 2020).

Finally, it should be noted that immersive installations in public areas can also be used to make people aware of their ecological environment. Some installations, similar to the *smart city* concept (Littwin & Stock, 2020), collect multiple physical data and translate them into another modality. For example, the installation *Particle Falls* (2008-2018) by Andrea Polli (Hetland, 2022), where air pollution data is visualised by translating it into streams of coloured pixels that are projected onto city buildings or the work *ATHsENSe* which processes not only atmospheric pollution levels but also temperature, luminosity, humidity, as well as noise level (Charitos *et al*., 2019).

2.2.3 Psychological and societal aspects

In order to immerse an audience in an open, public installation, the audience must first notice the installation and must then be attracted enough to spend some time viewing and (if applicable) interacting with the installation. Digital displays presenting ads or providing other kinds of information have become ubiquitous in public spaces and passers-by have become accustomed to them. As a consequence, in particular installations following the *poster model* (cf. section 2.1) may easily be disregarded due to a phenomenon that Müller *et al.* called *display blindness* (2009): if an audience expects to find boring content on a screen (e.g.: advertising on a display installed in a shopping street), they will largely ignore these screens. In their study, Müller *et al.* also proposed several strategies to increase the likelihood that people will look at public displays, distinguishing bottom-up factors (colorfulness, attractiveness, teh time that a display is visible, display size) from top-down aspects concerning the passer-by's perception of the display context (who is believed to be the display owner? Do the passers-by believe the content to be interesting or relevant for them, e.g.: local news or entertainment content?).

Beyond the generation of attention, it is well known that enticing interaction with displays in a public space is particularly challenging. Several models have been proposed in this context to describe how people interact with and around public installations: Brignull and Rogers, for instance, identified three *activity spaces* relating to (i) peripheral and (ii) focal awareness of the installation as well as (iii) direct participation or interaction with the installation (Brignull & Rogers, 2003). A similar model was used by Streitz *et al*. who designed their *Gossip Wall* as an installation composed of three zones (ambient, notification and interaction zone) where passers-by trigger different reactions depending on the zone they are currently in (Streitz *et al*., 2003). Finally, Michelis and Müller proposed the *audience funnel* model which distinguishes six different interaction phases (Michelis & Müller, 2011):

1. passing by;
2. viewing and reacting: e.g. head-turning or smiling;
3. subtle interaction: e.g. through gestures or movements;
4. direct interaction: more engaged, people may position themselves centrally in front of the installation;
5. multiple interaction: either by interacting with multiple sites/screens of the installation or by walking away and coming back;
6. follow-up actions: e.g.: photo taking.

In all these models, one can imagine a threshold that passers-by need to cross to move from one interaction phase to the next. In order to help them overcome these thresholds and to maximise the conversion rate between the phases, Müller *et al.* propose to firstly increase the attention raised by the installation (to pass from phase 1 to phase 2), to secondly elicit curiosity in the passers-by (to pass from phase 2 to phase 3) and thirdly to create and sustain a motivation for interaction to pass into the remaining phases (Müller *et al*., 2010).

Florent Aziosmanoff merges the interaction phases and proposes an alternative three-phase model to describe the relationship between the public and the artwork through social and psychological times (Aziosmanoff, 2010):

1. in the *short term*, usually a few seconds, the first contact is established, the public becomes aware that interaction matters and grasps first clues on how it works;

2. in the *medium term*, usually a few minutes up to a quarter -hour, the relationship is established and the public feels it has encountered the experience proposed by the artwork;
3. in the *long term*, usually over a day, week, or even month, the public comes back with a deeper understanding and an informed expectation to experience the artwork again, which may have evolved and may propose a renewed experience.

Attention and curiosity may be raised through surprise as well as the aforementioned strategies to mitigate display blindness. A very effective stimulator is also the presence of other people already interacting with the installation (a phenomenon known as the *honeypot effect* which is discussed in more detail below).

To further motivate interaction, an installation may try to challenge the experiencer and play on aspects like fantasy, curiosity and collaboration while simultaneously providing different choices and enabling the person «to maintain a coherent role in the public» (Müller *et al.*, 2010). Indeed, the potential for social embarrassment represents an important inhibiting factor for interaction in public spaces. Self-consciousness and the risk of ridiculing oneself in front of strangers can keep passers-by from engaging with an interactive installation as can the wish to stay anonymous and to not disclose personal data (Brignull & Rogers, 2003; Müller *et al.*, 2010). Moreover, aspects such as mere politeness (e.g.: not interacting with an installation if this would mean blocking a passage) or the adherence to social norms (e.g.: not performing certain gestures) and roles (e.g.: police or security personnel avoiding playful interaction) can act as further inhibitors.

Interestingly, social embarrassment often appears to be less of an issue for passers-by moving with a group. A group of friends, for example, may provide encouragement for interaction and social reassurance. Moreover, non-interacting group members may position themselves around the interacter, thus forming a physical barrier against the looks from strangers (Michelis & Müller, 2011). However, also a group of unknown individuals engaging with an installation can lower the perceived risk for social embarrassment in passers-by. Indeed, many studies found that «[w]henever a crowd of people had already gathered around the display, this crowd seemed to attract a lot of attention and other people were much more likely to also attend the display» (Müller *et al*., 2010).

This *honeypot effect* can be triggered both by the spontaneous interaction of genuine passers-by as well as by the planned intervention of actors or performers. Wouters *et al.* proposed a *honeypot model* in this context, at the heart of which they placed an *activation loop*, to describe the influences and trajectories between passive bystanders, observing audience members, engaged participants and experienced «dropouts» (Wouters *et al*., 2016). Moreover, they identified a *honeypot sweet spot*, i.e. an equilibrium state where the recruitment of new participants and the withdrawal of participants having finished their interaction balance out. For the installation considered in their study, Wouters *et al.* found a value of 3.1 participants. However, they noted that this sweet spot generally depends on system-specific constraints (e.g.: how many people can comfortably fit in front of the sensor and easily identify their corresponding avatars).

In conclusion, to successfully involve passers-by in an interactive public installation, one must first capture their attention (this can be achieved through technical parameters and by exploiting the honeypot effect) and then motivate them to participate. To achieve the latter, Brignull and Rogers (2003) recommend that the installation provide certain key information to the audience:

- How long does the interaction take?
- What will the interacting person get out of it?
- How does the interaction work and what steps are involved?
- Will the experience be comfortable (and not embarrassing)?
- Is there a quick let out to gracefully walk away from the installation without disturbing the ongoing public activity?

However, this information should not be given explicitly (i.e. via written or oral instructions etc.), but instead passers-by should be able to easily pick up the required rules by watching other people interact or simply from observation of the installation itself. The use of intuitive signage incorporating familiar shapes and symbols (e.g.: circles indicating where to stand or hands indicating interaction) can be very effective in the context (see also section 3.1). However, if signage can help set the rules, it can also limit the experience within the given rules. While children can usually do without them, adult passers-by often engage only when a code of behaviour is shared, either known in advance or provided on site. As immersive interactive installations open up new relationships with works of art that may seem to contradict the standard established in museums over the last two centuries, guidance or, more importantly, simply an authorization to interact should be provided to alleviate the social restriction.

2.3 Two immersive environments in open, public spaces

In open spaces, the environment sets the conditions for sensing, multisensory installations. Forum des Halles is the largest and busiest shopping centre in downtown Paris. Since its renovation in 2016, Forum des Halles is visited by more than 48 million customers and visitors every year. It includes public cultural facilities such as a library, a music academy, a hip-hop centre, and the Forum des images, at the beginning of the underground thoroughfare, rue du Cinéma, that connects the main underground public square, Place Carrée, the François Truffaut cinema library and the cinema multiplex, UGC Ciné Cité Les Halles. In 2022, the Parisian multiplex welcomed 2,22 million moviegoers, making it the most visited movie theatre in the world (Dumeau, 2023). The place is sociologically rich, with an exceptionally large and diverse population whose goals dictate their behaviour: a running pace about to miss a movie in the evening, a hurried stride that crosses the street to go to work during rush hours, a tired step that finishes the shopping on Sunday afternoon, a strolling one that starts it in the morning, a trampling on the spot that waits for an uncertain *rendez-vous* in the square. The place is fairly well adapted to digital art installations and ideal for field research and statistics with a large population of eclectic passers-by. Located indoors, it is isolated from any meteorological variations. The sun never reaches the place.
The applied electric light is fairly constant 24 hours a day, 365 days a year. However, the light intensity is high and the sources are numerous. The sound volume is also generally high and the sources are usually very diverse. They vary a lot over the day, over the week, over the month, and over the year. Therefore, any installation has to compete

with the many screens and lights that are the hallmark of shopping centres and tools for advertising – one among many others. It also has to find a way to be comfortably audible by the passers-by in a poorly controlled sound environment with high-level background noise and imposed sounds, multiple reverberation times, and the crowd activation of the Lombard effect, the less people can hear the louder they speak (Brumm & Zollinger, 2011), with up to 100.000 passers-by a day.

On September 22nd, 2018, *Ariadne's fibres* was inaugurated at Forum des images as a cybernetic reflection by Ikse Maître, for users, meteorological data and air quality, with infrared and colour sensors, computers and monitors. The sound composition was created by Vincent Hulot and the real-time 3D graphic environment was developed by Matthieu Courgeon. For the occasion, temporary installations by Ikse Maître and the collective des Vues de l'esprit were implanted in three squares in the Forum des Halles shopping centre with miles of floor markings that signified interconnected labyrinths as a reference to the Greek mythology where Ariadne's thread is the key to the way out. In the centre of Place Carrée, which could be reached along special paths through the marked labyrinth, in between two massive columns, stood *Primary Intimacy of being*, a mirror augmented by medical imaging created in 2014. Instead of the Minotaur, passers-by were confronted with a reflection of the human body as it can be examined by medical imaging. The mirror and labyrinths were removed a month later, while *Ariadne's fibres* is still on display and has been running every day since then.

2.3.1 *Primary Intimacy of being*

Art-science intention

Primary Intimacy of being is a mirror that reflects a human being, a woman, a man, as probed by X-rays computed tomography (CT), detected by positron emission tomography (PET) or revealed by magnetic resonance imaging (MRI). It shows the images in depth, three unique avatars of the viewers which are their images augmented by medical imaging. As the persons standing in front of the mirror move toward or away from it, they move into or out of the body through CT, PET or MRI. In *Primary Intimacy of being*, the viewers discover on their

Figure 3. ***Primary Intimacy of being,*** **a mirror augmented by medical imaging by Ikse Maître and des Vues de l'esprit in the middle of the flow of passers-by, Place Carrée, Forum des Halles, Paris, France on September 15th, 2018.**

own a morphological or metabolic intimacy that was previously hidden from them: that of the density of matter that supports and holds them, that of the energy that drives them deep inside, as installed under the Canopée at the top floor of Forum des Halles, or that of the water that constitutes them, as installed Place Carrée (Figure 3).

The three spatial dimensions have been tentatively addressed and ruled by Renaissance artists and scientists through the concept of perspective. They are now investigated everyday by 3D graphic renderers and radiologists. The augmented mirror provides an intuitive way for anyone to directly explore the otherwise inaccessible depths of the human body through the motion and movement of the user. They also offer a new perspective on the intimacy of one's inner body, which can be captured and shared with others, even before birth when still in the womb. Medical images are usually considered as ordinary objects and their potential intimate value is never really considered. The mirrors dynamically reveal unusual, disintegrated viewpoints on the human being, which might be difficult to acknowledge as being constitutive of a whole. They anticipate prospective issues when medical and self-images interfere with each other (Giraud *et al*., 2014).

Installation challenges

The mirror effect was emulated first by remotely tracking the motion of nearby passers-by – two simultaneously – using a Kinect® V1 sensor (Microsoft, Redmond, Washington) and FAAST middleware

(Suma *et al.*, 2011), second by remotely inferring their gender, using a separate camera (Logitech® HD Webcam C525) and the Shore recognition software (Küblbeck & Ernst, 2006). The avatars were based on CT, PET, and MRI whole body datasets of male and female volunteers with a 1 mm^3, 3 mm^3, and 4 mm^3 voxel size respectively. One million isospheres were generated and located at semi-random locations within a (1024×1024×512) 3D matrix, which was dense enough to allow clipping and full rendering of the magnitude of the medical datasets along any slicing plane. The sensor 3D and 2D referential frames were registered onto the reflected avatar space, mirrored onto the passers-by reference system such that, once detected and tracked, the passers-by could animate the displayed avatars, 64 million vertices each, rendered in real-time at 30 fps using OpenGL/GLSL acceleration (Khronos Group, Beaverton Or. USA). Overall, the system was very responsive. This made it possible to achieve a mirror-like illusion as most people are unaware of their own inner body, and as long as the avatar is correctly sexed and moves as they do.

The equipment included a 75-inch Samsung LCD, a Kinect® V1 sensor, a webcam, an HP Z800 workstation (Hewlett-Packard, Palo Alto, California) with a Quadro 4000 graphics card (Nvidia, Santa Clara, California), and a dual Intel Xeon processor at 2.40 GHz (Intel, Santa Clara, California). It was packaged in a black lacquered glass monolith (99 cm×264 cm×56 cm), supported from the inside by two 250 cm high triangular aluminium beams connecting two oak 5 cm thick boards. The installation weighed 320 kg and was self-supporting, making it robust, stable and safe. It was adapted for public spaces and no degradation was recorded during the month of exploitation at the Forum des Halles. It could even be installed outdoors if the Kinect® V1 infrared sensor was not blinded by sunlight during the day.

Immersion challenges

Primary Intimacy of being was installed in Place Carrée on the night of September 14th, 2018. It was positioned in between the two central columns of the square, right in the middle of the usual flow of passers-by. A connecting sound, composed by Michel Bertier, was played each time a new person was detected to attract attention and signal the start of the interaction. When idle after 30 seconds, the mirror displayed the following invitation message: «Come closer – The image in the mirror, it is you, but you are not the image in the mirror».

In the morning, people were definitely passing by. However, they walked around it. Some stopped in front of it. Some leaned against the monolith even after the initial sound and with their avatar reflected by the mirror but very few paid attention to this reflection and even fewer took the time to interact with it (Figure 4, left). There was a new labyrinth marking on the floor, a new glass black monolith on the way, but nothing happened. It slightly diverted the flow but interaction seldom occurred, not to mention immersion.

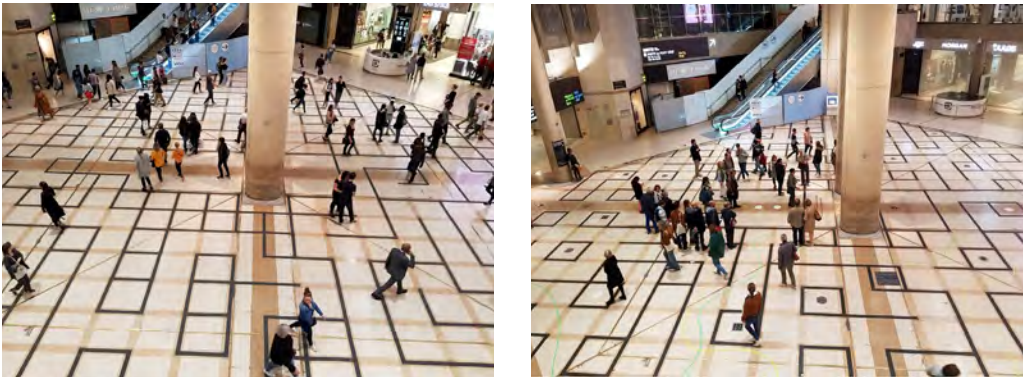

Figure 4. ***Primary Intimacy of being*** **on the spot in the middle of the black-marked-floor labyrinth, between the two central columns, Place Carrée, Forum des Halles, Paris. Left: The first day of the installation on September 15th 2018, at 3:08 PM. Right: Three weeks after on October 6th 2018, at 09:26 PM once signalling had been enforced on the floor with directing colour lines, informative texts, and three positioning white disks in front of the augmented mirror (©La métonymie).**

In the following days, the two other art works were set up and the labyrinths, marked on the floor and connected together with colour lines that could lead people to the art works. Informative texts were added onto the floor in the labyrinth deadends. Most importantly, three white disks were positioned in front of the mirror onto the floor to indicate possible positions for interacting with the mirror. Very quickly, passers-by effectively stopped and voluntarily interacted with the mirror, spending anywhere from 10 seconds to a few minutes in front of it. Lines began to form as more and more people wanted to try it, especially in the evening when people had time after the movie session. They organised themselves around the interaction zone so they could watch while waiting for their turn. Most of the time only one person was left to interact when two could have done it at the same time. The interaction zone then became a stage for performance. It was unclear whether the experiencers were seeing the reflection of their own inner bodies. *Primary Intimacy of being* displayed an unexpected prospective medical imaging technology that people collectively investigated.

Some experiencers were uncomfortable having their inner bodies revealed by the mirror in front of others. This expected social embarrassment had been previously tested in the more controlled situation of a black box, where subjects were asked to spend 3 minutes in front of the mirror, with or without the presence of an experimenter.

Most of the time, the illusion seemed to be effective and the identification worked, certainly because the reflected avatar mimicked their movements and because the discrepancies were blurred by the unusual body slicing. The appropriation by the passers-by then depended on the group. A regular passer-by was reported to confront the mirror every day when there was no one around to check *his* reflection and *his* health condition, which he considered good, provided that everything appeared to be in place inside.

Primary Intimacy of being is highly dependent on the experiencer's behaviour, so it may appear different to them each time it is challenged like it is for any mirror reflection they check from day to day. For intermediate times, *Primary Intimacy of being* can span over a large range of interaction durations as experiencers may spend some time first checking the relationship they have with the avatar, confirming identification, understanding the depth dimension, exploring the inner body, or challenging the system. Their presence in the installation in front of the mirror is implicitly personified by their reflection in the mirror. They are right there.

Once the possibility was offered and the user codes were shared, *Primary Intimacy of being* at Place Carrée grew a clear interaction zone in front of the mirror and shifted the centre of gravity of the crowd over the square so passers-by became easily notified about the happening even in the far ambient zone (Figure 4, right) as defined in section 2.3.

2.3.2 *Ariadne's fibres*

Art-science intention

Ariadne's fibres is a living mirror, a place where images, which move through us, are shared and exchanged. It reveals the expansion of our nerve fibres as it penetrates our bodies. In each and everyone of us, these fibres carry the nerve impulses which make possible and power our actions. *Ariadne's fibres* transmit information, convey images and drops of images of all kinds: these we hold, those that hold us, which make us, those we share (Figure 5). *Ariadne's fibres* plays inside out on three levels. First, it brings meteorological data from the surface of the city down to the third floor underground of Forum des Halles – where these parameters normally do not matter – to define its seasonal appearance. Second, it unveils the passers-by's inner body by reflecting primarily their central and peripheral nervous systems, secondarily their vascular, lymphatic, or muscular systems, and sometimes their bone system. Third, it displays images from the Forum des images, from current programs or developments, from their film collection, from workshops, from cinema, video, animation, video games, 360°, virtual and augmented realities.

Figure 5.
***Ariadne's fibres*, cybernetic reflection by Ikse Maître and des Vues de l'esprit in the crowded flow of the thoroughfare, rue du Cinéma, in Forum des Halles, Paris (©La métonymie).**

Ariadne's fibres captures and matches passers-by's movements. It is subject to the fluctuations of the crowd. Attached and endearing, they are driven by their own movements and incline towards those of others. *Ariadne's fibres* are enhanced by three-dimensional anatomy modelling and governed by fluid mechanics.

Ariadne's fibres originally intends, first, to inspire and stimulate renewed daily curiosity through evolving, interactive and reflective work; second, to accompany everyone in an exploration of the human being and their connections to the inside and outside world; third, to invite everyone to experience the process of discovering an unknown or unrecognised self, different others, underlying images, and the art and science that develop them; fourth, to open up both an original window on the Forum des images and a space for the collective imagination: image creation and transmission – medical imaging, cinema, fibre tractography, 360°, digital modelling, 3D animation, Virtual Reality, fluid mechanics, Augmented Reality, video games – information sharing within and between human beings, human-machine-human connections.

Installation challenges

The affordance of *Ariadne's fibres* is imposed by its location in the place of the large display case (7.7 m large and 4.5 m high) that Forum des images reserved for the installation at the beginning of rue du Cinéma. People are detected and tracked using 11 Kinect® V2 sensors (Microsoft, Redmond, Washington) over the length of the display and up to the middle of the street, 5 m away from the display while they are passing by.

The 3D referential frames of the eleven sensors are registered to a single reference frame using VR-mediated calibration attached to the actual setting such that the full 3D scene, which is digitally processed with the passers-by's avatars, can be rendered and mirrored as a side view on the wall and a top view on the ground.

Equipment includes eight 85-inch QM85F displays (Samsung, Suwon, Korea) and two M-Vision Laser 23 000 video projectors (Digital Projection, Oldham, United Kingdom) for visual stimuli, eleven XPC nano NC3000BA miniPC (Shuttle, Taipei, Taiwan) to drive the eleven Kinect® V2 sensors for motion capture, four Shape 50 amplified loudspeakers (Focal, La Talaudière, France), two Audiobeam 24ix (Holosonic, Watertown, MA, USA), and a 6i6 2nd Gen sound card (Focusrite, High Wycombe, United-Kingdom) for sound stimuli, two Z4 and Z8 workstations (HP, Palo Alto, CA, USA) with Nvidia Quadro P4000 (×1) and 5000 (×3) respectively. Real-time local weather information is obtained from *OpenWeatherMap* (OpenWeatherMap.org, n.d.).
On the right side of the case, an additional 49-inch display in portrait

mode provides a brief description of the installation along with a top view of *Ariadne's fibres* with a schematic dynamic representation of the detected experiencers in real-time.

The video and sound projectors were suspended from the ceiling, hovering 9 m over the passage, while the wall display and the rest of the equipment was hidden and protected behind a metallic cladding with two side technical cabinets. Due to the phase detection used by the Kinect® V2 sensors, protecting glass could not be installed, meaning that the sensors can easily be touched, dirtied, and slightly disoriented, which ultimately degrades the system calibration. Continuous tracking is an ongoing issue in *Ariadne's fibres* as, beyond the calibration, the depth information of the integrated field-of-view is often noisy and occulted by the many people passing by the street. Smoothing and denoising adds to the graphics rendering time of the 70 Mpx of the installation, introducing a slight latency of up to 2 frames.

Ariane's fibres was designed without the life cycle assessment (LCA) data necessary to evaluate, at least partially, the environmental damages linked to equipment manufacturing of such a setup. Consumption measurements are currently being carried out on the various elements of the installation with the intention to identify the best policy for on- and off-times according to energy consumption and the level of use of the installation site. However, an LCA would have enabled us to highlight the environmental impacts associated with digital uses, rather than confining ourselves here solely to energy consumption during use phase (Pohl *et al*., 2019).

Immersion challenges

The great challenge that *Ariadne's fibres* has faced since its inauguration in 2018 is, surprisingly, the attractiveness of one of the busiest pedestrian streets in Paris: it is an obvious passage that people cross, it is variably empty and incredibly crowded, it is constantly saturated with sound and visual stimuli, it is essentially a forum, the public space in which, we believe, immersion can and should take place.

First, the sound environment of *Ariadne's fibres* consists of twelve compositions of twelve different tracks, two of which are baselines that are played when no one is detected by the system, i.e. when the system is idle. Every other track of the composition currently being played is triggered by the detection of passers-by and played spatially over the six distributed loudspeakers along their trajectory in front of *Ariadne's fibres*, so that when ten experiencers interact, the full musical composition is rendered. It is as if each experiencer were one of the twelve instruments in *Ariadne*'s street ensemble. As the experiencers leave, their associated track is faded out and made available to newcomers. The compositions are played one after the other in a random order. The diversity of each composition is increased from day to day by the involuntary track selections made by the experiencers as they walk by. This diversity is important for the people who work at Forum des images, in the François Truffaut cinema library, and in the neighbouring shops. The volume of the sound is also a critical issue in this respect.

The broad dynamic evolution of the sound environment inside Forum des Halles, especially in the rue du Cinéma, makes it difficult to adjust the volume of *Ariadne's fibres* in a way that is acceptable to the neighbourhood and supports the interaction and immersion of the installation. In fact, the current volume is generally too low, especially during rush hours, to allow passersby to sense, perceive, or understand the connective and spatial effects intended by the soundtracks of the musical compositions.

Second, despite the large sizes of the available display video wall (4.6 m×3.9 m) and floor video projection (7.7 m×4.8 m) cumulating 70 Mpx, the visual environment does not fall within the people's normal field of view when they are walking up or down the street. The wall stands in the farthest corners of the eyesight and the ground falls under the footsteps. The system latency is hardly detrimental when the experiencers are already engaged with the system. However, when people are quickly passing by, the avatars are inevitably slightly behind them and thus not seen by them. The passers-by could more easily be captured by the others' avatars that appear on the wall or on the floor for the preceding people. However, this works neither during off-peak hours with too few people nor during peak hours with too many people. The density of passers-by is determinant for such visual triggers. As a result, only a small proportion of passers-by do notice the installation, a smaller number pay attention to it, and an even smaller number interact with it and appear to be immersed in it.

These proportions vary with the season, day of the week, and time of day, with peaks during holidays, weekends, and evenings. They also vary with the age of the passers-by. Nearly all young children will not only notice, but will be willing to approach and interact (Figure 6), unless, for some of them, the accompanying adults pull them away for some compelling reason of time.

Figure 6.
***Ariadne's fibres*, cybernetic reflection by Ikse Maître and des Vues de l'esprit with initial children and teenagers' engagement, rue du Cinéma, in Forum des Halles, Paris (©La métonymie).**

There is no sign, no indication, no rule, i.e. no code, except the dynamic signage attached to *Ariadne's fibres*. Although the interaction zone is clearly delineated by the ground video projection, it is not marked as such. It sits in the middle of the street and it is not distinguished from it except by the immaterial interactive video projection. When passers-by actually stop in front of *Ariadne's fibres* and begin to interact with the proposed artwork, they discover for themselves what governs the installation and how it is programmed. They often invent new rules and new ways of interacting. They infer new behaviours and sometimes effectively induce them. They imagine alternative uses of the artwork, which they spontaneously – by demonstration – or forcefully – by invitation – share with others.

Henceforth, they extend the interaction zone to the notification zone and dissolve the street ambient zone by involving all passers-by as actors or spectators of what is happening. *Ariadne's fibres* setup is thus better described by the model Brignull and Rogers introduced (Brignull & Rogers, 2003) where the direct interaction diffuses into focussed and peripheral awarenesses to cross the street. This process exemplifies the honeypot effect, which is most effective when it is initiated by a child – dragging the parents – or a group of children or teenagers – stimulating each other. So it is on holidays, weekends and Wednesday afternoons (when pupils do not have school in France).

Ariadne's fibres was created as a permanent artwork with very different interaction timescales in mind. Before each interaction with passers-by, the proposal is expected to be different each time: *Ariadne's fibres* evolves according to the season and the day's meteorology; the large droplets display film clips that are updated regularly. Once the interaction is initiated by passers-by: the musical composition is enriched, an avatar is associated with each of them. While they stay and continue to build the interaction: the small droplets generated by their avatar grow, the avatar they are playing can push or fling these droplets away, they can enter the movie clip large droplets, they can change the elasticity and viscosity of their avatar by their own movements, their avatar will start to get entangled with the neighbour's after some engagement time… And when they come back later – an hour, a day, a week, a month or a season later – the environment has evolved, as the wind might be blowing on the surface of the Forum des Halles, the type of avatar has changed. In wintertime, the movie clips have been updated with the new program, the droplets look different, the turbulences are higher and passers-by start dancing. Once again, *Ariadne's fibres* creates new alternative realities in which experiencers are engaged and present.

2.4 Conclusions

The engagement of the passers-by in an immersive experience is a complex and subtle dynamic living process that requires the conjunction of social and psychological parameters beyond the artwork in order for reality to shift, and for resonance to occur. The presence of the passers-by in artworks installed in public spaces is difficult to evaluate. An art exhibition, a theatre play, a dance performance, or an opera can be reviewed only by those who wanted to attend it. They can judge it as a success or a failure after they have obtained a ticket or at least after they have arrived at the venue. Only very few people share this cultural habit and the evaluation remains limited among the whole population.

In public spaces, everyone is entitled to evaluate the immersive experience they have just had. Only very few passers-by may stop by but these very few can add up quickly among the overall numerous population, who happen to be passing by, without any intent or expectation towards art at that moment. So, the rate of stopping by is certainly not a fair indicator of the reception of immersion in public spaces.

The new open narratives, that immersive interactive installations develop, address the general public in a broad cultural democratisation without any distinction of age, gender, social or ethnic origin. They face demanding technical, ecological, psychological, social, and even administrative and legal issues at large. They often fail but they sometimes succeed and the achieved resonances cope with the numbers. Immersion in public spaces plays with the curiosity that drives human beings out of the flow to take side roads and sometimes to be present here-and-now, in an artwork, as a surprise.

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3. The evolution of immersive technologies over time

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ABSTRACT

In 1989 the artist Monika Fleishman disclosed a cutting-edge technology, Virtual Reality, long time before explored by Ivan Sutherland (Ward, 2024) and Morton Helig (Norman, n.d.). This was the origin of the exploitation of both Artificial Reality (1975) and Virtual Reality – on one side Myron Kruger (Krueger, n.d.), on other side Jaron Lanier (Lanier, n.d.) and Thomas Zimmerman (Zimmerman, 1985). In 1978 Andrew Lippman developed the Aspen Movie Map, enabling virtual navigation along the streets of Aspen thanks to a sequence of pictures linked together. In 1991 Carolina Cruz-Neira, Daniel J. Sandin and Thomas A. DeFanti developed the Cave Automatic Virtual Environment, better known as CAVE[1], a cube with retro-projected surfaces enabling one explorer to accompany small groups to visit a virtual environment. In 1993 Infobyte, a VR company located in Rome, developed a set of interactive Virtual Reality applications mainly devoted to exploring the application field of cultural heritage, Basilica Superiore di Assisi was the first application followed by

Note 1.
Recalls Plato's allegory of the cave.

Nefertary's Tomb, Rome Colosseum, St. Peter Basilica, Raffaello's Rooms, etc. Almost all the virtual environment created by Infobyte offered an enhanced degree of interaction allowing the user to virtually restore or switch from one scenario to a related one. Interactive Virtual Reality applications were designed to be experienced by one user per time, even the CAVE allowed only one explorer even if accompanied by some partners. An interesting exploration of the potential field of application of IVR in education was devoted 1997 to particularly difficult scientific topic, the magnetic field, and its laws. Students had the chance to enter in this universe and observe the behaviour of an electrical particle thrown within a magnetic field having the additional option to tune all the key parameters and see the outcomes. In addition, we need to specify the meaning of immersion, does it mean emotionally involved, blurring reality with virtuality?

3.1 Introduction

After the extraordinary success of online communication technologies including, of course, social media, it is foreseeable a potential coming cultural revolution due to immersive *communicative experience.*

After more than thirty years we reopen the folder of immersivity in a social dimension enabling creatives to express themselves in open public spaces. Is *immersivity* an interesting and innovative *communicative experience* to be enjoyed together with other citizens, breaking cyber-isolation? Let's start from one of the key building blocks of immersivity.

3.2 Breaking the two dimensions barrier

In the 1960s we had a dream… to put our head inside the cyber world and look around. This was probably what Ivan Sutherland (Kirk, 2018) dreamed when he conceived the Sword of Damocles. But let's start from some of the basic steps that led to *virtuality* and the concept of *digital immersivity*. Most conventional images offer a two-dimensional projection of a three-dimensional scene[2]. To feel part of the scene, to feel immersed we need to perceive the environment as much real in the three physical dimensions.

Note 2. With the exception of some techniques such as dotted images [the viewer must focus beyond the picture to get the 3-D effect termed Random dot stereograms (RDS) and pattern shaped stereograms (PSS)] or stereo viewers.

Stereo pictures were invented in the first half of the 19th century by Wheatstone (Stereographs), at almost the same time that Nicéphore Niépce (and later Daguerre) invented photography. Stereo viewers were very popular from the 19th century till the first half of the last century. They are based on the idea of simultaneously showing slightly different images of a scene to each eye, which reflects how each of our eyes will see the same scene slightly differently, our brain *merges* the two images into one three-dimensional scene, leading to an illusion of reality. These images are termed stereo pairs, the first step in the evolution of stereo visualisation. Stereo pairs must be generated or acquired from two points of view separated by the intraocular distance. Stereo pairs can be used without any additional device by simply tracking a pencil moving toward the pair of images while trying to focus on the two images.

In 1891, thanks to Louis Arthur Ducos (Association Louis Ducos du hauron), a special technique enabling three-dimensional visualisation using a single image was released. The basic idea was to merge the stereo pairs into the same image by using two different colours (e.g.: red and blue) to represent the left and right images. By looking at the single image through glasses fitted with filters that eliminate the coloured image of the *other* eye, it is possible to obtain an illusion of a three-dimensional image. Such a technique, usually called anaglyph[3], works best with black and white images, even if it was and still is often used with colour images. Of course, the colour palette is strongly reduced in this case because of the dominant filtering colour. Nevertheless, this appears to be one of the easiest and least expensive ways to offer three-dimensional scenes to large audiences (e.g.: at the movies).

Note 3. Stereograms are like anaglyphs, but they use patterns of dots to code stereo pairs (random dot stereograms or RDS and pattern shaped stereograms or PSS), where users view the image by trying to focus beyond the scene.

In a similar way, the stereo pairs can be merged not into the same print but on the same projection screen using cross-polarised light. This should be light polarised in the vertical plane for the right eye and light polarised in the horizontal plane for the left eye.
By wearing glasses fitted with cross-polarization filters, the unwanted image is then filtered out, resulting in a stereoscopic image.

This method works better with coloured images, and the glasses required are very cheap and easy to use. This was the *magic* on the first 3D movie *Watching Bwana Devil* (Bwana Devil 2021) at the Paramount Theatre (1952). Additional methods that are used to convey the appropriate image from the stereo pair to the appropriate eye have also been developed, although these involve using more expensive and intrusive devices.

Some years later, when three-dimensional computer graphics became feasible, the same idea of stereo imaging led to the development of various techniques. Shutter glasses represented one of the basic methods of conveying the correct image to each eye. A relatively high frequency monitor (e.g. 120 frames per second) displays the two images from the pair (e.g. 60 frames each), and a sync signal (e.g. transferred through an infrared interface) synchronizes the displayed image with the appropriate shutter on the glasses, blinding the opposite eye.

The glasses use voltage-activated liquid crystal shutters to blind the appropriate eye when the *wrong* image is displayed. Other than this, the merging of images by the brain etc. is the same as for the stereoscopic techniques mentioned previously.

Other methods may use one or two separate displays or printed representations, but they are still ultimately based on the same principle as before. So, we have panoramic screens, video tables, 3-D sets.

Extending the range of three-dimensional representations, holograms are another potential way to break through the barrier of two-dimensionality[4] as we will see in different astonishing applications later.

Note 4.
Refer to the Virtual Cockpit or the use of lasers to *write* 3-D shapes onto the retina (both of which were developed by Tom Furness).

3.3 Computer graphics and the third dimension

A second building block to enjoy immersivity in virtual *universes* relies on computer graphics. In the last sixty years the field of computer graphics has been revolutionised, starting from Ivan Sutherland's Sketchpad in 1962 and reaching its current apex in visual games and mobile phones and tablets interactive Virtual Reality.

Three-dimensional computer graphics has evolved from wireframes to Boolean operations on elementary solids (Platonic solids) and surfaces, Bézier and Coon's surfaces, meta-balls, parametric and implicit surfaces, and more. From the early *wireframe* representations of 3D scenes through Lambert flat shading, Gouraud and Phong algorithms, raytracing and radiosity methods to image-based rendering and more. These different methods and algorithms are usually grouped together under the catch-all term of *global illumination* algorithms, developed by one of the most active special interest groups under the flag of SIGGRAPH[5].

Note 5. SIGGRAPH is the ACM Special Interest Group in Computer Graphics. Cfr. http://www.siggraph.org and http://www.acm.org.

In the 1990s the focus of computer graphics research moved from the defence (e.g. R. Reagan's Star Wars) sector to the entertainment industry as it did the special effects (fx) sector towards experimentation with virtual actors and virtual sets. The outcome were several enhancements that have surfaced in the last thirty years, including particles, flames, morphing, bump mapping, procedural mapping, fur rendering, motion capture, lip syncing, digital scenography and more. A subset of the virtual actor field of investigation tackled the world of artificial life and virtual creatures. One of the first example was *Stanley and Stella: breaking the ice,* a video created by Symbolics (Wikipedia, 2024) graphics division (McMahon, 2023). These include virtual entities equipped with autonomous behaviour based on a set of simple rules (Terzopoulos, 1999). Such actors do not obey key framing rules, they act autonomously, just like the crowd on the deck of the *Titanic* in the well-known movie or the army of Uruk-hai in *The Lord of the Rings: The Two Towers* movie. Now is time to focus on the evolution of Virtual Reality.

3.4 Virtual technology

The world of virtual technology is wide-ranging and does not have well-defined borders. As is often the case in new disciplines, particularly those in the field of computer science, the boundaries of this technology are difficult to define; they constantly change as subsets of the field move from being innovations to becoming everyday tools. We can refer here, for instance, to Artificial Intelligence and to its *domain* during its earliest years, which included Computer Vision and Fuzzy Logic and more recently Machine Learning.

In the field of Virtual Reality there is still some dispute over whether VR needs to be *immersive* and *intrusive*; computer-Augmented Reality and Extended Reality are still considered close to the limit of this technology, and in addition a number of VR applications are very closely linked to the multimedia field; therefore, in order to avoid postulating an improbable definition of interactive VR or immersive experience, we refer to a taxonomy that covers the full panorama of the objects and methods typical of the virtual domain. We must first define *intrusive* and *nonintrusive*, which are terms that distinguish virtual experiences that require the use of *ad hoc* wearable equipment (helmets, data suits, gloves, sensors, cyber devices) from experiences generated by high-tech environments equipped with sensors, capture cameras, display walls and other devices that does not need to be worn. This delineation has led in the past to the use of the expression *Virtual Reality* to indicate intrusive experiences (as opposed to *Artificial Reality*). The concept of *immersivity* deserves a specific paragraph.

3.5 Immersivity

Once depicted the different technological components let's now consider immersion. We need to specify the meaning of *immersion*: does it mean *emotionally involved*, *blurring reality with virtuality*? Another delineation, and one that is undoubtedly more arduous, is that between immersive environments and no-immersive ones. This type of classification is complicated by the fact that different levels of immersivity are required by different applications, and that the ability of each user to be *immersed* in a particular virtual environment differs. There are those of us that become so deeply involved in a story that they cry when something bad (or even good!) happens, while there are others that cannot *switch off* from reality even when they are using the most realistic and immersive virtual environment.

After all, 3-D immersive rooms, 3-D audio, force feedback and other such technologies are all useless if the subject does not want to be immersed, while a book or a simple display might be immersive enough for a particularly receptive subject. This aspect is easy for anyone that has become engrossed in a book or a TV show to understand. Essential requirements for immersivity are undoubtedly the ability to freely naturally interact with the scene and the ability of the system to provide real-time feed- back (we call this IVR, or Interactive Virtual Reality).

During the early developmental stages of this technology, interactivity was bounded by the limited performance of both the hardware and the software used. 3-D stereo viewing was a major bottleneck in such systems. The generation of computer graphics, especially 3-D computer graphics, is not just a number-crunching process; it is a resource-constrained process in general. The graphic pipeline must be perfectly tuned to ensure high quality real-time graphics.

Each time we interact or simply move the viewpoint in the virtual universe, by turning our heads for instance, the Virtual Reality system must recalculate and render the entire scene[6]. If we want the scenes to change smoothly, we need at least eighteen or more frames to be created per second, and if we want to enjoy three-dimensional effects (stereo effects), the system must do this twice, once for each eye.

Note 6. To partially solve this problem radiosity algorithms helped a lot.

The human brain, the most important component of the human vision system, interprets stereo pairs in real time to provide us with meaningful information.

3.6 Evolution of Virtual Reality as the key for immersion

The concept of immersion and immersivity is usually intertwined with Virtual Reality technology and its evolution. Information scientists were not the first to consider realistic immersive artificial experiences. In the mid-sixties the movie industry started to experiment with new formats and technologies that were intended to generate more spectator interaction. Such systems included Cinerama and the Cinemascope.

Already in the 1950s Morton Heilig (Norman, n.d.), a forerunner of multimedia experts, developed the idea that theatre could involve all the senses thus immerging the spectator in the scene. He coined the expression *Experience Theatre* depicting this concept in his 1955 paper *The cinema of the future* (Robinett, 1994) this work led to the conception of Sensorama in 1957 and to the construction of its prototype and related patent in 1962. Sensorama machine was very similar to some we saw at gaming centers years ago.

This was the first attempt to immerse a spectator into a multisensorial experience. Of course, since there was no interaction with the *artificial world*, this was not a Virtual Reality experience in a conventional sense; however, it was undoubtedly one of the ancestors of modern virtual experiences and prophetic of future trends in this sense. Unfortunately, the Sensorama didn't succeed commercially. Let's highlight the fact that major part of Virtual Reality experiences was aimed at individual users, some of them offered the opportunity to share the visual experience in small groups but only one person was *leading* the experience (e.g. Cave).

Virtual Reality has inspired many other artists, such as painters, sculptors, and movie directors. Several science fiction movies have dealt with these topics. The original version of *Tron* (1982) introduces the dynamic of relations among different characters that populate computer architecture. *The Lawnmower Man* is the movie that made Virtual Reality popular. *The Matrix* proposes a metaverse directly connecting real and virtual, and why do not mention the *The Thirteenth Floor*, a matryoshka of virtual worlds where no one apparently knows if his reality is the the *real* one[7].

Note 7.
Brett Leonard*, The Lawnmower Man*; Josef Rusnak, *The Thirteenth Floor*; Andy and Larry Wachowski, *The Matrix*, and its sequels.

At the end of the 1960s Myron Krueger, after working on various projects such as Glowflow, Metaplay, Psychic Space (Krueger, n.d.), created and experimented with artificial interactive environments (which today would be defined as being *not intrusive*). He created an environmental technology called Videoplace (Krueger, n.d.), which was environmental in the sense that the artificial system surrounded participant and responded to his/her actions. Videoplace was a relatively flexible and user-friendly technology since it could be experienced without the user having to wear special instruments. At the same time, however, there was also a line of research on the technology of sensors and displays designed to be worn and therefore relatively bulky (now defined as *intrusive*). In 1969, at the University of Utah, Ivan Sutherland, the father of computer graphics, created what he called *the ultimate display*, a head-mounted display that was able to generate and manage two stereoscopic images and thus generate a three-dimensional scene in real time.

This was the origin of the exploitation of both Artificial Reality (1975) and Virtual Reality - on one side Myron Kruger, on other side Jaron Lanier (Lanier, n.d.) and Thomas Zimmerman (1985). Myron W. Krueger coined the expression *Artificial Reality* in the middle of the 1970s: he was referring to both the Videoplace technology (Krueger, n.d.) and the head-mounted display (HMD[8]) envisioned and prototyped by Ivan Sutherland. These two technologies represented two different paths toward the same goal: total body immersion in computer-generated environments that is convincing that it is just like a *real* experience. In 1976 P.J. Kilpatrick, who collaborated with the University of North Carolina, connected radioisotope manipulators to a somewhat stylised graphical world. Kilpatrick's system, GROPE II, created a virtual simulation of the mechanical arm in a stereoscopic viewer. By 1978, the concept of force feedback was implemented in North Carolina. The same year Andrew Lippman developed the Aspen Movie Map, enabling virtual navigation along the streets of Aspen thanks to a sequence of pictures linked together. However, in some cases, when the door to interactive Virtual Reality was opened, all that was found was a long, dark corridor: it was simply too early.

Note 8.
Technology that enables three-dimensional vision.

In the 1980s, along with the spread of Unix and workstations, a new vision of technological development arose in the field of literature: William Gibson's seminal work *Neuromancer* (published in 1984, coincidentally the same year in which Orwell's famous novel about the future, which introduced the concept of Big Brother, was set). In this book, Gibson popularised the term *cyberspace*, which referred to a single artificial reality that could be experienced simultaneously by thousands of persons all over the world.

At the end of the 1970s, several coordinated projects in the field of Virtual Reality were activated at MIT[9]. One of these, named Put-That-There, was based on a three-dimensional tracking system coupled to a rudimentary voice-controlled interface. In 1983 an interesting high-end application of Virtual Reality appeared on the scene due to research performed under the leadership of Tom Furness III. Starting in 1966, he began to develop and test, at the Wright Patterson

Note 9.
Massachusetts Institute of Technologies.

Air Force Base, an incredible array of methods and technologies aimed at transferring information to and communicating with a pilot engaged in combat, including methods that the pilot could use to set and activate weapons whilst being subjected to high g-forces. He eventually came up with the idea of transferring information to the pilot by graphically projecting all the information onto a *virtual screen* outside the cabin. The technology needed to realize this virtual cockpit was developed during the 1970s, and a prototype of the *Super Cockpit* was realized in 1981 and the Visually Coupled Airborne Systems Simulator (VCASS) demonstrated at Wright-Patterson Air Force Base (Ohio) in 1982.

This technology remained top-secret until 1983, when was made publicly available. Later Furness moved to the University of Washington and dedicated himself to the study, development and fine-tuning of a new technology based on the idea of drawing three-dimensional images directly onto the retina of the user's eye with a laser beam (Human Interface Technology Lab).

The subsequent evolution of immersive Virtual Reality is closely associated with NASA, the national aerospace agency in the U.S. In 1984 Michael McGreevy from NASA started to become interested in Furness's work. Knowing that the cost of the Super Cockpit helmet was one million dollars, together with an entrepreneur and a budget of only twenty thousand dollars, he decided to demonstrate that the flat screen monitor from a pocket television could do the same job. They constructed a helmet that used two liquid crystal displays to supply the stereoscopic images, special fibre optics to generate the illusion that the images were further away than they really were (2,5 cm), and a magnetic position sensor that determines the direction of sight. In the meantime, Scott Fischer moved from MIT to NASA, and under his direction the size of the helmet viewer was reduced significantly and became known as *Krueger glasses with stereo viewers*.

In 1989, Jaron Lanier, the general manager of VPL Research, a Californian society that has focused on *virtual technologies* from its inception, coined the term *Virtual Reality* to group together all virtual experiences. Continuing our excursion through the technological evolution of this field, Scott Fischer commissioned VPL Research to develop a high-resolution fold sensitive glove (the Data Glove)[10].

Note 10.
Data Glove, one of the enhancements developed and tuned by Jaron Lanier, is an innovative physical interface shaped like a glove that includes fibre optics, mechanical transducers or bending resistors, which are used to translate gestures into commands that control both virtual walkthroughs and virtual object manipulation.

Later, NASA introduced a magnetic position and orientation sensor (Polhemus, n.d.) that enabled the bending of each finger to be linked to a particular point in three-dimensional space. This ability enabled the Data Glove to be used to point to and manipulate objects in a three-dimensional artificial reality.

The laboratories at NASA developed many advanced projects using this glove. Indeed, Warren Robinett, the creator of Easter eggs in ATARI video games, established glove use conventions[11].

Note 11. Gestures, positions of fingers, and other conventions involving actions and motion (closed fist = grab, index finger pointing forward = forward motion, etc.).

From 1989 onwards Virtual Reality has undergone constant and frenetic development, from the total body suit (data suit) to new types of helmets, including Virtual Research's Eye Gen III, a CRT-based helmet, the Sym-Eye glasses and the *million dollar* helmet by CAE Electronics[12], more recently the Zeiss one.

Note 12. The same helmet used in the action movie *Blue Thunder*.

In parallel with these technological feats, we have the performance of the artist Monica Flaischmann[13], one of the first Virtual Reality experience made available in Europe. It was held on CeBIT 1989 (Hannover, n.d.), an interactive visit to the Alexander Platz metro stop in Berlin. Later we experienced the VR systems of W-Industries and Division Dimension; Sense8 and Autodesk's World Toolkit (both software products); and, in terms of hardware, FakeSpace's Boom (Fakespace labs boom 3c) and the University of North Carolina's CAVE (Cruz-Neira *et al*., 1993) all in the 1990s.

Note 13. In 1989 the artist was part of GMD Society for Mathematics and Data Processing (Gesellschaft für Mathematik und Datenverarbeitung); later, in 2011, was merged with Fraunhofer Society for Applied Research [Fraunhofer-Gesellschaft für Angewandte Forschung e.V. (FhG)].

Virtual Reality has always been a fascinating realm, the appearance of some early applications late in the 1980s generated both curiosity and concern. Some suggested that Virtual Reality was a gateway to the world of dreams (*dreamland*). Of course, as often happens for emerging technologies, early approaches were not easily accessible to potential end-users. On the one hand, the overall cost of the bare technology (hardware and software) combined with the cost of application development was a significant barrier for quite a long time.

In addition, the overall quality of the experience was not good enough at that time to enable its use in some potential fields of application (e.g. culture, education, fashion, etc.). Nevertheless, several artists, interested, by definition, in new media exploration and in unusual modes of expression, tested and experimented with Virtual Reality from the very start.

Flight simulators, long used to train aircraft pilots, were one of the first interactive Virtual Reality applications. To ensure success to these experiences we need to pose our attention to the perception mechanisms, the tight relation between sight and vestibular system, the feeling of movement and speed simulated by acceleration and not less important the different relevance of foveal vision and peripheric vision, video games programmers know very well this aspect. Expressions like *virtual worlds, virtual environment, virtual universe* have been coined to describe similar advanced research projects.

To understand the relevance of this sector, consider the attention paid by the media in the 1990s to this emerging technology and the actual interest in the Metaverse and in general to immersive virtual environments.

As a conclusion to our review of the evolution of VR, we could note that in the 1990s, changes in the political approach to defence (DoD) in the United States have provoked a significant movement of human resources from defence research to toys companies such as Mattel, Nintendo, Sega, and later Sony all entered the field of Virtual Reality, including in addition, Warner Brothers, Walt Disney, MGM, and Sony DreamWorks entertainment companies. So, it should be remembered that, after being neglected for twenty years by academic researchers, immersive Virtual Reality became a field of research *by definition* as soon as this technology was applied to the field of entertainment. This coincidence emphasises a strange irony: applied research in the field of entertainment is economically more profitable than that performed in the defence sector.

In 1998 this technology was considered appealing by Disney, who decided to include IVR in theme parks as an *extra* to test its appreciation and collect feedback. It was crystal clear that IVR experiences cannot be offered to mass audience using *laboratory* equipment, it was necessary to completely re-engineer the devices to ensure, safety, robustness of devices, hygiene and more.

A meaningful example was the outstanding Aladdin application created by Disney and hosted for a short time at the Epcot theme park before being moved to Disney Quest. This installation required twelve Silicon Graphics Onyx Reality Engine II servers which provided the incredible graphics engine of this real-time adventure that was experienced by four people at the same time using *gator-vision* viewers mounted on *rock lobster* helmets. Viewers and helmet duly re-engineered by Disney.

In 2000, Disney inaugurated the new theme park a full digital park, Disney Quest (Orlando). The concept of this park was completely different from the traditional and mainly open aire Disney parks, which visitors navigate easily as they can see the Snow White Castle, the Golf Ball, the Tree of Life, etc. Disney Quest was a blue *sealed cube*: visitors entered the ground floor in a big room, as it happens in briefing rooms, with two opposite *aquarium walls*. After short time the door on the opposite side opened and they left the room four floors up. From this point onwards they could follow two 3D mazes, one named *Adventure* the other *Creativity.* The need to be lost in *space* is essential to experience the completely different adventure *distant few minutes* each other, from *Star Wars* to *Pirates of Caribbean*. Few years later Disney Quest was dropped, it didn't meet the expectations of Disney's followers and the cost to update the experiences was too expensive compared to the incomes.

In the 1990s Virtual Reality was considered a potential pervasive technology offering benefits in different fields, from human computer interaction to culture. Many times, a limited application of VR was successful, typically interactive walkthrough in virtual scenarios, even if the potentialities of interactive Virtual Reality were incredibly wider using virtual sensors, virtual actuators, autonomous behaviours of digital objects, enhanced interaction among entities and more. The ability to reverse physics and natural behaviour of objects was really appealing this later one become a key subject of science fiction movies.

To complete this brief overview, it is it is necessary to add that the 1990s Interactive Virtual Reality already embraced what we term now *Metaverse,* sometimes even more advanced than todays' approach. A branch of this technology has been applied to surgery and health applications, enabling less invasive therapies to be performed, such as laparoscopy and telesurgery thanks to remote controlled robots[14].

The key limitations at that time were due to technology and the lack of big key players investing relevant resources to make the Metaverse dream come true. The concept of Metaverse[15] probably dates back in the 1990s when Bruce Dammer introduced the Digi-gar-

Note 14. **Relevant research studies were carried out in the 1990s by Col. Satawa (US Army).**

Note 15. **The science fiction nov*el Snow Cra*sh by Neal Stephenson originated the term *metaverse* (1992) – https://en.wikipedia.org/wiki/Snow_Crash.**

dener, the avatar of a gardener remote controlled by humans; more recently the movie *Avatar* outlined this idea to create digital *proxies* operating in a cyber universe. Some thirty years ago, we remember Habbo Hotel social game: players can store assets as in a kind of digital Monopoly game even in this scenario thief use to act stealing virtual furniture and cloths.

As it often happens, Interactive Virtual Reality succeeded in some fields and was considered not enough mature in others. Consequently, IVR reached the so-called *calm phase*, and another potential pervasive technology came of stage the *World Wide Web*. Thanks to the success of the world wide web technology, sometimes due to the limited bandwidth re-termed world wide wait, several *dialects* generated by vertical customisations of the original markup language, the Standard Generalized Markup Language (SGML), were created, among them the Hypertext Markup Language (HTML), eXtended Markup Language (XML) and lastly VRML.

VRML (Brutzman, 1996) was introduced by Mark Pesce during SIGGRAPH '93. His demonstration started with a short movie showing a building; then he displayed a picture of the same building, before finally showing a VRML interactive model of it. The latter representation was far smaller than the previous two in terms of storage size. The workshop, entitled *VRML Equinox*, announced the birth of this new technology.

In the following years application of VR technology can be classified mostly as *virtual walkthroughs*. They involved almost no interaction with the objects in the virtual scene and therefore represented a very limited use of the potential of VR[16], as briefly already described.

Note 16.
Although there are some interesting applications using haptic interfaces and enhanced interactions.

Then it was the time of SAS Cube (SAS3 – Maurice Benayoun, David Nahon 2001), Second Life (Linden Lab 2003), Street View (Google 2007). On the hardware side Oculus Rift (Palmer Luckey 2010), Facebook purchase Oculus VR, Project Morpheus (SONY 2014), Cardboard (Google 2015). Michael Naimark was appointed Google's first-ever *resident artist* in their new VR division (2015), and lastly, till now, the Metaverse (META 2021). Nowadays powerful devices are in the pockets or on the desktop of citizens, display devices ranging between cartoon (Google VR, n.d.) *googles* and affordable cost head mounted displays offer the opportunity to feel immersed in a virtual 3D scenario.

3.7 Flooded by immersive experiences

Digital technology till now has mainly acted as a human isolation technology, computer mediated human relations or even a *loneliness relation* with your terminal, your smartphone, gaming console or laptop. It happens that friends sitting around a table at breakfast or lunch do not interact among them but watch their smartphones sending messages or browsing the web sites. It is time to develop digital technology improving socialisation, taking citizens out from their apartments joining the variety of agora, public spaces in city squares, theatres, stadiums. After a long training in watching DVDs and video streaming, we know that there are some shows that must be enjoyed in group: football matches, scary movies, science fiction are better experienced together with other people.

The key assumption is that immersion needs to be triggered not only in a circumscribed space where visitors have to come, but also throughout the digital network between institutions and people using different platforms, not only within their own *bubble* but together, not only with dedicated equipment but also using capturing sensors for a minimally-invasive collective and social experience either in the public space or remotely to gather the citizens and to cope with potential confinement and distant cultural access. This immersion paradigm shift – in which passers-by, visitors, or internauts take part – will improve the institutional flexibility and cultural offering, stimulate cultural consumption, increase revenue, and enhance social impact. This will require arts and cultural institutions to establish corresponding business models and foster new cultural consumption patterns to meet the upcoming needs (e.g. remote 3D interaction,) of the public digital usage. There are already, scattered around the world, several public spaces that are suitable for such cultural offer think, for instance, to airports and malls, people use to spend time in such facilities and why not enjoy some cultural experiences even related to local assets?

In the last decades, citizens experienced different public space digital exhibits[17] such as *Uffizi Virtual Experience* (Centrica Imagine More, 2016), *Van Gogh: The immersive experience* (Fever, 2021), *Galileo all'Inferno* (StudioAzzurro, 2012), or *Virtual Zoo 7D* (Victorio Kaisar, 2017) and more. Advances in immersive technologies may rep-

Note 17. The Atelier des Lumières opened in 2018 in Paris (Atelier des Lumières, n.d.).

resent competitive advantage to the media industry – e.g., Extended Reality (Statista, 2024) – and are an important driver for the experience economy, enhancing breadth, depth and intensity of artistic performances or the visitors' experience at arts and cultural institutions.

Yet, advanced immersive solutions are usually neither readily available nor broadly accessible:

- they require specific developments that can hardly be carried out by most institutions;
- they are usually confined into a virtual or actual close space where conditions, either human or environmental, can be fully mastered;
- they are usually limited to cinematic experience in which bystanders play little or no role;
- the inherent affordance of immersive propositions, which sometimes rely on complex software interfaces and expensive equipment, is questioned by the currently evolving world health situation.

A relevant step forward can be due to the exploitation of large interactive Virtual Reality theatres in public spaces, where citizens can experience both media companies' products and creatives' artefacts. In such public spaces citizens can interact with the application, even in connection with other citizens located in public spaces pertaining different countries and cultures. Some of early experiences in this field of remote cooperation among artists were experienced on the *Ars Electronica Festival* (Ars Electronica, 2024) many years ago, or by *Art+Com* (ART+COM Studios, n.d.) and more recently on the pandemic, especially in the field of music and performing arts in general. There is a need to create a global framework for Cultural Creativity, by designing and developing efficient, cost-effective software and hardware (projectors, computers, cameras, and detectors), multi-user, multi-site, multi-platform non-invasive immersive and interactive users' experiences – sorry for the long list of buzzwords identifying the key characteristics. Both software and hardware need to be optimised to offer users a hassle-free, less costly sustainable and enhanced immersive experience to favour the approach to culture as an emotionally engaging *communicative experience* in public spaces.

3.8 Enhanced reality

Enhanced reality (also termed *enriched reality*) can be thought of as a version of the real world that has been enriched with computer-generated information. There are two main approaches to producing enhanced reality: the first provides a direct view of the real world but with digital information superimposed, while the second acquires the *shape* of the real world (in two or three dimensions), merging the real world with other data to produce a comprehensive output image[18].

Note 18. Often used in the field of archaeology to reconstruct the original shape of buildings.

The second approach is usually easier to achieve than the first because the merged world that results is more accurate and stable. This because the merging process involves finding the same features in the two-dimensional images and overlapping them accurately before the combined scene is outputted.

Both enhanced reality and Virtual Reality have ignited the imaginations of moviemakers, as can be seen by watching *Blue Thunder* and *Firefox*. Both helmets featured in these films superimpose digital information onto the real world and are typical devices used in ER. One of the most well-known of these helmets was the *one-million-dollar* display by Kaiser Optics.

In the 1990s one of the most popular solutions for obtaining enhanced reality was based on Virtual IO goggles, an inexpensive device that offered good Virtual Reality and enhanced reality performance. Early in 21st century, Carl Zeiss began to sell a set of goggles. Such devices have been used for various applications, such as for technical assistance and repair, in location-dependent information systems, and for physical item retrieval. There are also solutions that are used by car mechanics to aid with disassembling and reassembling parts of the engine. Since the early appearance of enhanced reality (e.g. the visual instruction to remove the toner cartridge from a printer) the potentialities were evident in several fields such as navigation in huge physical archives or route assistant on bikes and cars (Wikitude, 2023).

3.9 Projections – Viewers

We should at this point make a distinction between input and output devices. Input devices: these include simple navigation devices (e.g. a mouse) as well as those that track movement using specific positional sensors. Sensors can even be placed in virtual objects to react to our stimuli. Common navigation peripherals possess two to six degrees of freedom, while position sensors usually offer six degrees of freedom using different technologies and thus different reaction times, accuracies, and operational ranges. If deep interaction with the virtual world is our goal, another family of devices is required. Such devices range from the common keyboard to objects created *ad hoc* (e.g. SpaceBall, Magellan) and physical or virtual replicas of real control devices such as those used to simulate F1 racing cars or jet fighter cockpits. The three main functions already mentioned (navigation, tracking and interaction) are often performed using a single device, such as the data glove, which is equipped with a position sensor and interprets a language based on gestures (e.g. W. Robinett's conventional gesture language).

Output devices: these include different types of displays, from helmets (HMD or head-mounted display) that may or may not generate three-dimensional effects (stereo view), to panoramic screens (e.g. the *Visionarium*). Apart from audio/visual devices, these may use haptic devices, hydraulic and mechanical actuators to produce movement and acceleration, as in the case of flight simulators and adventure rides in theme parks.

Other I/O devices specifically designed for Virtual Reality applications include force and tactile feedback devices, smell simulators and artificial noses, and thermal feedback devices. High relevance in this context, considering their popularity, are the devices dedicated to the entertainment and computer games market, such as six degree of freedom controls, force feedback controls, stereo glasses, and others.

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4. An eye on immersive experiences and installations. Observation of several case studies

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ABSTRACT

Within the framework of the European Research *ARTCAST 4D*, dedicated to the exploration of immersion concept and of immersive technologies and their applications, a collaborative consortium of experts was asked to curate the collection of diverse case studies. The mission was to collect approximately 50 case studies with interesting features coherent with the overarching research objectives. The focal point of these curated case studies is the nuanced exploration of immersive technologies and their applications within the expansive domains of culture and the arts.
The collected case studies originate from creative entities dispersed globally, exhibiting variations in presentation over time. The case studies have been collected through an online questionnaire useful for the consortium to help curating the array. Several sections regarding different case studies features have been designed in order to better collect the information needed. Consequently, the questionnaire has been spread in between the consortium. Following the collection process, these case studies

have been analyzed, and their findings have been mapped and organized into tabular formats. These tables function as comprehensive repositories, offering a structured overview of the essential features encapsulated within each case study.
The culmination of this collaborative effort is a curated collection that not only showcases the diverse applications of immersive technologies but also serves as a resource for understanding their impact within cultural and artistic spheres. By transcending temporal and geographical boundaries, this collection, through the expertise of the consortium, tries to report a global overview of immersive experiences and installations, offering insights into the creative manifestations and applications of immersive technologies on a broad scale.

4.1 Collection of the case studies

Within the context of the *ARTCAST 4D* research, an observational and data collection activity was undertaken regarding various case studies related to immersive experiences and installations across diverse contexts and application domains. Within the research, among the various questions addressed by the team, the collection of the aforementioned case studies proved essential in responding to the research question: how are immersive experiences currently conveyed?

The purpose of the case study observation activity is to gain an overview of immersive experiences and installations in general. Within the research framework, the data collection activity was considered a fundamental step to better understand the research themes and the technologies described in the literature context. Theoretical concepts such as presence, sensory involvement, engagement, embodiment, and isolation provide insight into the phenomenon of the *immersive* sensation and how it is perceived at a theoretical level. However, an examination of the state of the art through significant case studies on immersive installations and experiences helps comprehend its practical development with technologies and devices currently in use. For the collection of experiences and installations, support from the *ARTCAST 4D* consortium was sought, consisting of partners from various parts of Europe with varying levels of expertise in immersive technologies. From the consortium, approximately 57 case studies were gathered through an online questionnaire created using Google Forms, circulated among the partners. The subsequent subsection delves into the questionnaire structure. Once collected, a preliminary screening was conducted based on the level of information available to ensure a comprehensive description of the case study (some were eliminated from the list due to insufficient information) and the technological level presented by the experience or installation. For the purposes of the research, only case studies featuring the involvement of technological devices in the immersion process were deemed noteworthy. The remaining case studies were subsequently analyzed and categorized based on the indicated sources from which valuable information could be extracted. Videos, images, descriptions, and other relevant materials were examined to discern patterns and elements of description across the collected case studies.

4.1.1 Questionnaire structure

The collection of case studies was conducted through the formulation and dissemination of an online questionnaire, developed utilizing Google Forms and shared with the European project consortium. The outcomes of the literature review phase of the *ARTCAST 4D* research helped the construction of the questionnaire, coupled with a preliminary analysis of select case studies identified by the researchers overseeing this study.

The questionnaire aimed to compile a pertinent set of case studies pertaining to immersive experiences across various fields of application. While contacting the *ARTCAST 4D* partners, the objectives of the investigation, along with the pertinent information to be addressed, were introduced and elucidated to the participants in advance. The collection has been based on the expertise of the contributors inside the field of immersive experiences, installations and technologies in between the research project partners.

The questionnaire was divided into six sections, with different collection aims. The initial section comprised inquiries soliciting profile information from the participant completing the questionnaire,

encompassing details such as full name, affiliation, and e-mail contact for potential follow-up. In the second section of the questionnaire, participants were tasked with furnishing comprehensive details about the selected case study. Specifically, they were prompted to provide information such as the title, year, location, synthetic description, rationale for presenting the particular example, and, lastly, its objectives and fields of application. This involved selecting from a pre-defined list of proposed possibilities or proposing new ones.
The third section concentrated on delineating the involved actors. The inquiry initially directed attention to individuals or entities commissioning the experience. Subsequently, it expanded to encompass additional actors who might be involved, emphasizing their multidisciplinary backgrounds, roles in the design process of the immersive experience, precise identification (if available), potential requirement for technicians in the setup of the experience/installation, and the characterization of the targeted user demographic.

The fourth section delved into more granular details concerning the installation characterizing the presented case study and the augmented experience it offered. Specifically, the questionnaire prompted participants to specify the type of technology and technological tools employed, and to indicate the envisaged duration of the installation or exhibition, before honing in on the features that defined the overall experience. In this context, emphasis was placed on sensory stimulation, interaction modalities, potential for personalization, collaborative elements, storytelling, and gamification.
The fifth section of the questionnaire pertained to the design process of the installation and the associated experience. Commencing with an inquiry into the testing phase of the case study, it sought to ascertain whether such testing occurred in a laboratory or in the field. Following this, an open-ended question solicited information about the principal phases of the design process, while a multiple-choice question probed the software utilized in support, with the specific aim of identifying whether open-source alternatives were employed. In conclusion, the final section of the questionnaire was devoted to the compilation of supplementary materials related to the case study, including external links, videos, images, and other pertinent documents aimed at offering a more comprehensive understanding.

4.1.2 Questionnaire results

As previously stated, a total of 57 case studies were gathered through the online questionnaire, surpassing the initial Key Performance Indicator (KPI) of 50 cases. The initial collection underwent mapping and scrutiny, with case studies lacking a discernible level of technology or providing insufficient information being deemed unsuitable for the research objectives. The mapping process revealed gaps within the technological categories of interest, necessitating the inclusion of additional case studies corresponding to specific domains, such as Augmented Reality applications or immersive experiences related to the sense of scent. The domains not covered by the sample set collection from the partners were included to ensure a comprehensive examination of all technological aspects and experiential features. This broader coverage aimed to facilitate a more comprehensive understanding of the overall situation.

Finally, a total of 52 case studies were reported and observed.

Despite the limitations of this study, based on the expertise and perspectives of contributing partners for sample set construction and the absence of adherence to statistical significance, the endeavor provided a snapshot of the current landscape of immersive installations and experiences. Furthermore, it contributed to identifying information gaps that necessitate further investigation, useful for the *ARTCAST 4D* research next steps.

4.2 Distribution of the case studies

The collection has been organized into Google Sheets documents to facilitate an overview of the distribution of case studies in relation to the research items declared pertinent for observation. The cases were distributed into clusters in order to observe the fields of application, the actors participating into them, their roles and background, the technology and tools involved, the experience characteristics (time, duration, interaction elements, general content) and some parts of the design process adopted to design them. Next paragraphs report the observation declared.

Case study name	Year	Location
Falls from the Sky, Aerosplane, Flutter	1993	Villa Panza, Varese, Italy
Nefertari Tumb	1994	Italy, Rome, Infobyte SpA
Magnetic field explorer	1994	Italy, Milan, Politecnico di Milano
Galileo all'Inferno	2005	Milano
CELL - Centre for Experiential Learning	2009	Italy, Padova, QBGROUP
Digital dynamic version of Chinese ancient painting "Along the River During the Qingming Festival"	2010	Shanghai Art Museum, Shanghai, China
Primary Intimacy of being	2011	France, Paris, Museum of art and craft
Rain Room	2012	Globally itinerant
Mekorot FieldBit	2014	Mekorot company, Israel
MUSME - Museo della Medicina	2015	Padova Italy
See me through you	2015	France, Paris, Cité des sciences et de l'industrie
Infinity Room	2015	Istanbul, TR, Istanbul Biennal- Zorlu performing art center
Immersive Space Series - OOT	2016	San Francisco Bay, Youtbe and Google Offices
Oculus Nohlab	2016	Istanbul, Tophane-i Amire
Dreams of Dalì	2016	St Petersburg, FL, USA, Dali Museum
CWRU AR headset	2016	CAse Western Reserv Unviersity, Cleveland, USA
Museo di Monte San Michele	2017	Italy, Gorizia, Sagrado
The Eye of Mars	2017	Billettes Cloister, Paris, France
Rome's Invisible City VR	2017	online
Kremer Museum	2017	Online
Collio XR	2018	Collio Region, Carnia
Van Gogh Exhibition	2018	Moving exhibit
Ariadne's fibres	2018	France, Paris, Forum des images
Skin awareness	2018	London, UK
Nuii, VR adventure	2019	Spain
The Hidden Music of Leonardo	2019	France, Paris, Louvre
Exstasis	2019	Italy, Sicily, Santa Caterina d'Alessandria church, Palermo pzza Bellini 1
Giostra del Saracino - CarraroLAB	2019	Arezzo, Tuscany, Italy
Mona Lisa VR	2019	Louvre, Paris, France

The Anatomy Lesson of Dr. Nicolaes Tulp	2019	Maurithsius museum, The Hague, NL
Illuminated Art Attisholz	2020	Switzerland, Solothurn, Attisholz Areal
Earth	2020	Church of San Francesco d'Assisi, Palermo, Italy
MoMa virtual tour	2020	MoMa, New York, USA
El Roque de los Muchachos Visitor Centre	2021	La Palma, Canary Islands (Spain)
Gymkana Camp de Morvedre	2021	Camp de Morvedre, Valencia (Spain)
Ruta Maestrat	2021	Maestrat, Castellón (Spain)
Anima Mundi	2021	Italy, Palermo, Orto Botanico, Via Lincoln 2
Goliath	2021	online
MMANZONI 23 – Perpetual Immersive Experience	2021	Milan, via Manzoni 23, Italy
VR Workshop in Polimi	2022	Politecnico di Milano, Milan, Italy
MARSS (MusAB from science to society)	2022	Museo Astronomico di Brera, Milan (Italy)
Palacio de la Aljafería	2022	Zaragoza, Aragón (Spain)
OVR Dark	2022	Valencia, Spain
Olafur Eliasson: Trembling horizons	2022	Turin, Rivoli, Castello di Rivoli
I AM (VR)	2022	Triennale Milano, Milan, Italy
The Dreamachine	2022	London
Deep Space 8K	2022	Ars Electronica, Linz, Austria
Yayoi Kusama - Infinity Mirror Rooms	2022	Hirshhorn Museum and Sculpture Garden, Washington, DC
TokyoLAB	2022	Tokyo
OSNI 2 Cartier	2022	rue Robert Esnault-Pelterie, 75007 Paris, France
Room to Breathe	2022	Outernet space, London, UK
Chaplin's World	2023	Switzerland, Corsier-sur-Vevey
NAO	2023	Alicante, Valencian Community (Spain)
David Hockney - Lightroom - Bigger & Closer	2023	Lightroom space, London, UK
Frameless	2023	London
Spaces in Between	2023	Outernet space, London, UK

Figure 1.
All collected case studies table reporting the name, year and location.

4.2.1 General information

Case studies collected have a temporal range in between 1993 (*Falls from the Sky, Aerosplane, Flutter*, three light and audio installations from Micheal Brews) and 2023 (*Spaces in-Between*, three interactive and immersive artworks from Outernet, London). Geographically talking, the cases have been taken from different parts of the globe, from Asia (teamLab works from Tokyo), Europe (Olafur Eliasson, Refik Anadol, several others) and North of America (MoMa Virtual Tour application). The case studies encompass various experiences, installations, digital applications for VR / AR technology deployment, artworks, and research items, all of which exhibit immersive characteristics in their implementation. Depending on the case study, creators are from a broad spectrum of applications and backgrounds, ranging from artistic endeavors to company profiles and beyond. Figure 1 reports the list of the case studies collected with the case study name, year of release and geographical provenance/allocation.

Regarding the distribution of the case studies on their field of application, it is worth to consider that, because of the nature of the *ARTCAST 4D* research, cultural heritage and art emerge as the predominant clusters in this distribution, followed by entertainment, and education. Entertainment field of application encompasses experiences and installations designed to provide visitors with an entertaining experience. The field of education pertains to case studies wherein the ultimate goal of the experience or installation is oriented towards a didactic purpose (Figure 2).

4.2.2 Actors involved

Through the online questionnaire conducted as part of the data collection process, insights were gathered regarding the roles and multi-

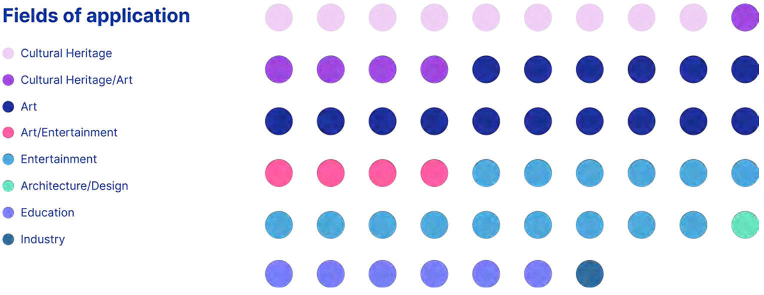


Figure 2.
Graphic representation of the collected case studies distributed according to their fields of application.

disciplinary nature of the individuals involved in the experience and its design process. The questionnaire also provided details regarding the commissioning of the collected case studies. As part of the research, additional efforts were made to delve deeper into the roles of the actors involved, through online interviews. The following are the key aspects performed during the questionnaire phase.

Commission

Relating to the nature of the majority of the case studies collected, because of the general research scope, cultural institutions and research centers emerge as the primary entities taking on the role of commissioners, occasionally engaging in collaborations as stakeholders in the commissioning process. When mapping the case studies, in between the different rage of scenarios emerging, it is notable how many of them are financially supported from private investors, companies, studios/offices; state organization entities account for the minority of the case studies observed (Figure 3).

Figure 3. Graphic representation of the collected case studies distributed according to the commission stakeholders involved.

Roles

The collected data reveal that in the vast majority of instances, the involved actors in the design and management process of the case studies possess multidisciplinary backgrounds. This highlights the necessity for diverse roles and knowledge domains in the creation of an immersive experience. Even if parts of the questionnaire were design to collect more precise information on the multidisciplinary roles involved, some of them have been elaborated starting from the experiences content and context. From this observation on the actors roles, it is clear the majority of them could be described as designers

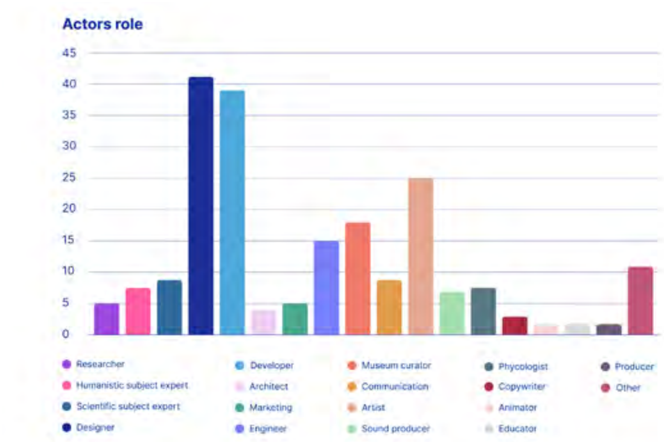


Figure 4.
Graphic representation of the roles involved into the cases collected.

and developers. Second large group defined is the artists one, and then the museum curators and the engineers. Some roles were combined in a major category, such as for example communication designers, product and interaction designers, merged into a single general role *designer*; this is also for artists and developers as well (Figure 4).

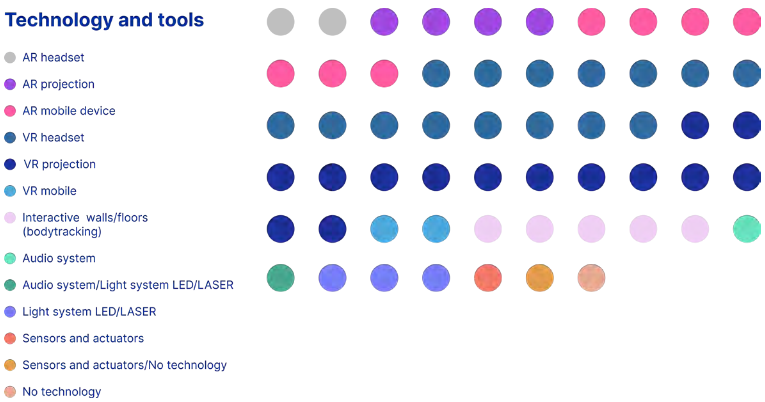
4.2.3 Interaction and experience characteristics

This section reports the observation of the distribution of the case studies regarding the technology and tools involved, the duration and the interaction modalities of the experiences.

Technology and tools

The involvement of technology domains provides essential defining elements for the immersive nature of the experience, with each technology potentially utilizing various devices and tools in its implementation. Therefore, sub-categories were created by merging the general technology field with specific devices to enhance precision in cataloging the experiences. For instance, the Virtual Reality technology domain was further delineated into VR-headset (e.g.: Meta Quest 2), VR-projection (using projectors on walls), and VR-mobile (through iPad, smartphones, others) clusters, based on the specific tools and devices utilized. The graphic representation (Figure 5) illustrates that Virtual Reality is the predominant technological domain among the case studies, with VR headset being the most extensively utilized tool when considering the specificity of devices. VR projection as well represents the second largest group of the case studies distribution. In the AR clusters, the majority of cases involve the use of a mobile device. Another identified technological cluster is Interactive Surfaces, which includes LCDs, front- and retro-projected walls, and floors displaying content that users can interact with; these devices often incorporate body tracking systems.

Figure 5. Graphic representation of the collected case studies distributed according to the technology and tools involved.



Duration of the experience

Another aspect considered during the data collection from case studies was the duration of the experience: if it was categorized as *temporary*, the experience had a defined start and end date. If not, it was classified as *permanent*, indicating that it continues to the present time. The case studies are evenly divided between permanent and temporary ones, although some do not provide accurate information and are therefore labeled as *not specified* (Figure 6). The 26 temporary experiences that were mapped out have been further analyzed, with a specific focus on their duration. Among these, 8 experiences do not have a consistent duration as they often involve itinerant experiences characterized by variations in event type and location, making it challenging to accurately classify their timing. Figure 7 reports the duration on time of the temporary experiences.

Interaction modalities

To gain a better understanding of the nature of the case studies, key aspects regarding the interaction process between users and the experiences have been examined. Initially, the cases were mapped

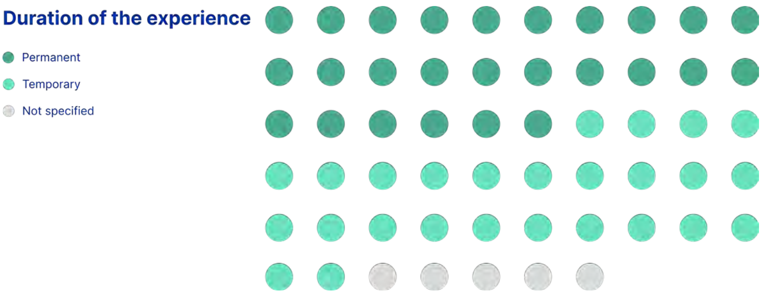


Figure 6.
Graphic representation of the collected case studies distributed according to their duration.

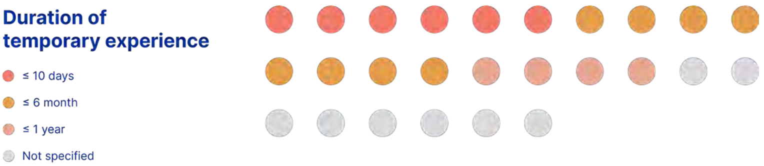


Figure 7.
Graphic representation of the collected case studies distributed according to the time lenght duration of the temporary ones.

based on the level of user participation: Figure 8 illustrates the distribution of case studies across the different categories of interest. The first cluster pertains to *stationary users* within the experience, who simply observe without engaging in any actions.
The largest cluster involves *users who can move within tangible space*, indicating that users have the ability to physically navigate the space. The next category is *users who interact with physical or digital objects*, where users not only move but also engage with external elements in their experience. Following this, there is the cluster of *users who can move within digital space*. Lastly, the cluster *users who can actively collaborate with others* involves cases where collaboration among users is a central aspect; however, only a few cases reported this interactive feature.

The sensory stimulation given by the case studies have been also mapped, distributing them in between the number of human senses involved per experience. As shown in Figure 9, the majority of the case studies collected present two senses involved into their immersive experience, all of them referring to the sense of vision and of hearing. The primary target of sensory stimulation is reported to involve two senses. Additionally, there are cases where three senses are stimulated, incorporating the sense of smell and the sense of touch, depending on the nature of the experience. The first is given by releasing smells and aromas through machines, and the second one

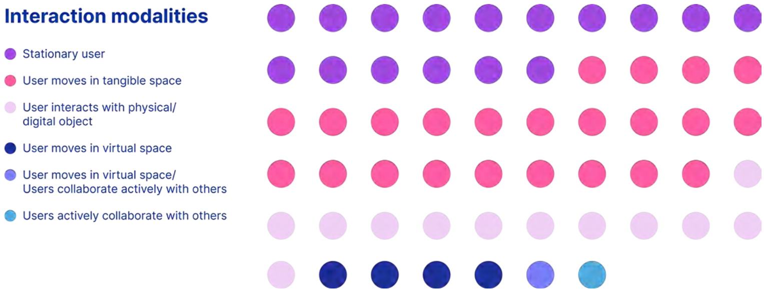


Figure 8. Graphic representation of the collected case studies distributed according to their main interaction modalities.

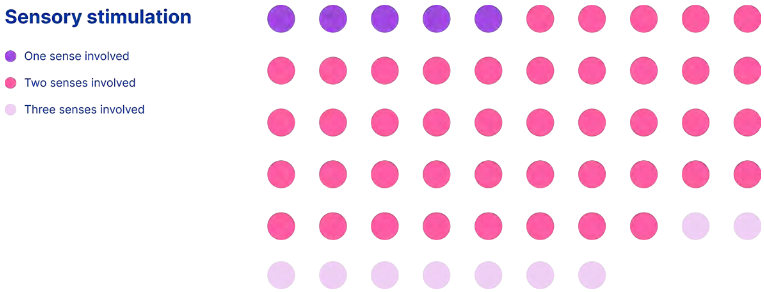


Figure 9. Graphic representation of the collected case studies distributed according to the number of senses involved.

through haptic devices or textural components/surfaces. Some case studies targeted just one sense, focusing either on vision or hearing.

4.2.4 Experience content

This paragraph reports the distribution of the case studies relating the nature of the content displaced by the experiences/installations.

Content attributes

Additional interaction characteristics of the experiences have been analyzed based on the content presented. Figure 10 illustrates the distribution of cases concerning the presence of various features, including playful elements, narrative elements, and personalized content tailored to the users. It is noteworthy that none of the observed case studies reported specific characteristics that could be mapped, with the largest cluster in this analysis categorized as *no distinctive elements identified*.

Content nature

A more in deep exploration of the content nature of the experiences have been carried out, observing the distribution of the case studies

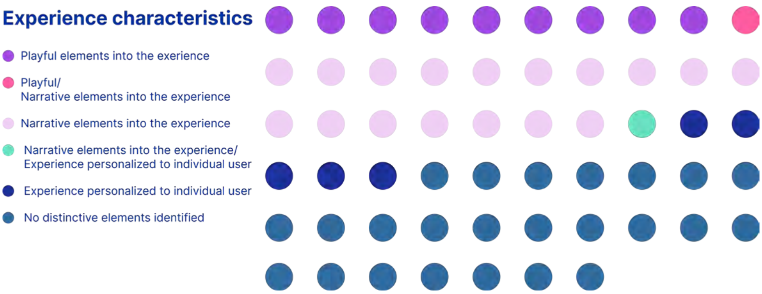


Figure 10.
Graphic representation of the collected case studies distributed according to the attributes of their content.

in relation to the characteristics of their displacement. The categorization of the case studies in this context is based on the nature of the content showcased within them. Figure 11 shows the results of these distribution. It is evident that a substantial portion of the case studies predominantly features animated content, present in 24 cases. Other case studies also incorporate the reproduction of tangible elements (e.g.: 360° videos) or static content. However, case studies employing technological components such as light/laser patterns and audio experiences are less prevalent in the sample. Furthermore, 3 instances are categorized as presenting tangible content. Some case studies present more than one characterization in this context, transitioning from static to animated content or presenting overlays between tangible and digital content.

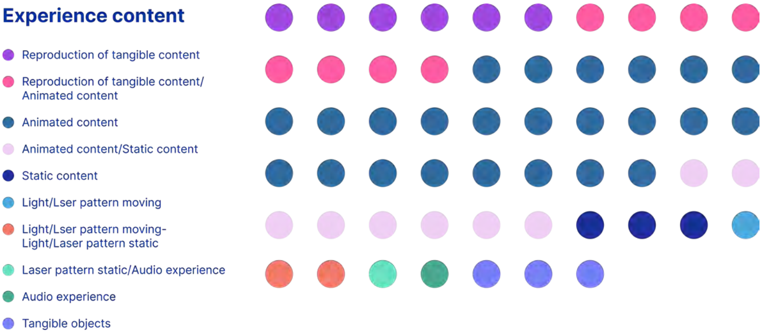
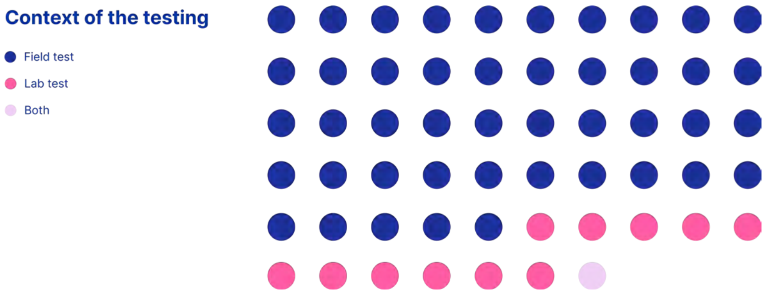


Figure 11.
Graphic representation of the collected case studies distributed according to the nature of their content.

Context of testing

Insights related to the design process of the experience were collected from the fifth part of the questionnaire. However, the research context demanded a deeper investigation into the design process arguments, which was subsequently pursued through direct interviews with creative actors such as studios, companies, and professionals in the field, presented in next chapters. What emerged from the questionnaire relating the design process is the context of testing of the case studies: as shown in Figure 12, experiences were distributed in order to identify whether the testing occurred in the field, in a laboratory (Lab), or in both conditions. The analysis of the sample revealed that the majority of cases (45) were field-tested, while only one case underwent testing in both conditions.

Figure 12. Graphic representation of the collected case studies distributed according to the context related to their testing phase.



4.3 Evaluating the most interesting case studies

The examination of the collected case studies provided an insightful overview of the landscape of immersive experiences and installations, offering an initial insight into this field. However, within the context of the *ARTCAST 4D* project, this compilation alone proved insufficient to address some of the most pertinent research inquiries. As evident from preceding paragraphs, while the questionnaire's structure and specific inquiries were relevant to the research objectives, the information and responses gleaned from the case studies do not encompass all the elements required.

The research questions tried to be answered from this activity are *How are immersive experiences currently conveyed?* and *How are immersive experiences currently developed?*, respectively RQ2 and RQ3 inside the research project.

To explore deeper into these inquiries, the research team opted to deepen the collected results by conducting online interviews directly with the creators of the experiences and installations. To facilitate the feasibility of the interview activity, a careful selection of the most interesting case studies for the research had to be conducted.

In order to evaluate the interest of the case studies, they have been mapped assessing them in relation to the previously defined Keys of Immersion.

The Keys (Presence, Cognitive and Emotional Engagement, Sensory Involvement, Embodiment, Isolation) are strategic concepts regarding the definition of immersion from a theoretical point of view. They have been defined during the first literature phase of the *ARTCAST 4D* research. Crossing the case studies with the Keys enabled an examination of the alignment between the consortium partners and the researchers conducting the investigation regarding experiences that facilitate a sense of immersion. The most interesting ones were then selected for a more in-depth study (online interviews, described in the next chapters). To assess the perceived level of immersion in each case study, the five researchers working on this section of the *ARTCAST 4D* project conducted a cross-evaluation seeking intercoder agreement (Creswell, 2014). Each of them assigned a rating from 1 to 5 (where 1 stands for a very low expression of the Key of Immersion and 5 for a very high one, while 3 has a neutral value) and relied on the information available, especially on online video resources.

The extreme values for each Key of Immersion as described in the following.

- Presence: not feeling there (1) to feeling there (5);
- Cognitive engagement: distracted (1) to focused (5);
- Emotional engagement: boredom (1) to excitement (5);
- Sensory involvement, the scale refers to the number of senses involved in the experience: from 1 to a maximum of 5. It should be noted that for case studies such as *Rain Room* from Random International studio, broader human sensations were also considered like humidity, proprioception, etc;
- Embodiment is connected to the level of agency enabled by the case studies. It was detailed as: (1) users have no control or possibility to interact within the experience, they are just passive observers; (2) users have little agency, for instance,

they can move in the tangible or digital space, changing her point of view; (3) users can somehow interact with tangible or digital objects (e.g. controllers). Associated with number (4) was some level of agency, materialised by the possibility for users to modify tangible or digital objects. Finally, the highest agency could be enabled by (5) users' possibility to modify the interaction process itself;

- Isolation: not isolated (1) to completely isolated (5).

Once the evaluation metrics were shared, each researcher individually assessed each case study not to produce bias. Then, the results of the activity have been analysed by calculating the mean and z-score for each Key of Immersion. The z-score [defined – per each Key of Immersion – as z = (average of the evaluations per case study - mean of the average values of all the case studies per Key of Immersion) / standard deviation] was adopted as it describes the position of a raw score in terms of its distance from the mean when measured in standard deviation units and it allows to compare standardised results. In order to have a synthetic value identifying the immersiveness of each case study, the average of the z-scores they obtained for each Key of Immersion was calculated. Finally, to get a comprehensive overview and compare the collected case studies, they were organised into quartiles based on their values (Figure 13).

The most notable examples of immersive experiences were identified within the fourth quartile (>75%), and the 13 case studies included were selected for further analysis through semi-structured interviews.

4.4 Discussion

The collection of case studies provided an interesting overview into immersive experiences and installations across various fields, spanning different time periods and geographical locations. However, it's important to acknowledge that these case studies, gathered based on recommendations from experts within the *ARTCAST 4D* consortium, do not potentially constitute a comprehensive or statistically representative sample. Therefore, they may not capture the full breadth

	Case study	Z score average
1st quartile	OVR Dark	1,630353997
	Anima Mundi	1,068468036
	Museo di Monte San Michele	0,8437413786
	Dataspace - Deep Space 8K	0,8339345419
	Borderless	0,7519289708
	VR Workshop in Polimi	0,6662670129
	Nefertari Tumb	0,6369714561
	The Dreamachine	0,6219550155
	Rain Room	0,6150606896
	Mona Lisa VR	0,6035151725
	Collio XR	0,5329723834
	Nuii, VR adventure	0,5318550052
	Dreams of Dali	0,485945094
2nd quartile	Exstasis	0,4276529023
	OSNI 2 Cartier	0,3914360856
	Mekorot FieldBit	0,3886759265
	Giostra del Saracino - CarraroLAB	0,3471365633
	NAO	0,3013777324
	Goliath	0,292851393
	Van Gogh Exhibition	0,2917366499
	Spaces in Between	0,2619936598
	Earth	0,2461157702
	Illuminated Art Attisholz	0,2388911195
	I AM (VR)	0,1994063617
	Infinity Room	0,1684357829
	Kremer Museum	0,1116737114

		Z score avera
3rd quartile	Frameless	0,078506272
	El Roque de los Muchachos Visitor Centre	0,061586671
	Room to Breathe	0,050894176
	CWRU Hololens	0,030372736
	Oculus Nohlab	0,019618933
	See me through you	0,0033659731
	MARSS (MusAB from science to society)	-0,14183074
	Rome's Invisible City VR	-0,18246626
	Immersive Space Series - OOT	-0,29640587
	David Hockney - Lightroom - Bigger & Closer	-0,32182324
	MoMa virtual tour	-0,4694258
	MANZONI 23 – Perpetual Immersive Experience	-0,52293871
	Olafur Eliasson: Trembling horizons	-0,53607293
4th quartile	MUSME - Museo della Medicina	-0,56292124
	Falls from the Sky, Aerosplane, Flutter	-0,57443769
	Galileo all'Inferno (spectator pov)	-0,59054359
	Skin awareness (spectator pov)	-0,6319705
	The Hidden Music of Leonardo (spectator pov)	-0,72860206
	The Anatomy Lesson of Dr. Nicolaes Tulp	-0,73884870
	Primary Intimacy of being	-0,83427018
	Palacio de la Aljaferia	-0,97929284
	Ruta Maestrat	-1,083160
	Ariadne's fibres	-1,0887893
	The Dynamic version of Chinese ancient painting	-1,1261766
	The Eye of Mars	-1,1615987
	Gymkana Camp de Morvedre	-1,1631215

Figure 13.
Case studies distributed according to their z-score evaluation.

of immersive experiences and installations, potentially leading to significant gaps, especially concerning historically important case studies in this field. Each contributor to the collection may have been influenced by their own professional and personal perspectives when suggesting cases, which could introduce biases. This was evident in the distribution of case studies by the research team, where professionals working within specific time periods, geographic regions, or fields of application tended to recommend case studies related to their respective areas of expertise.

While the collection of case studies may not provide statistical significance, it nonetheless offers a compelling snapshot of the panorama of immersive experiences and installations. The cases span a diverse range, encompassing experiences, installations, digital applications, and artworks. These case studies demonstrate a wide array of fields of application, including art, research, cultural heritage, industrial, commercial, and promotional purposes, among others. Educational field as well is largely encompassed. It's noteworthy that the majority of the cases, aligning with the focus of the *ARTCAST 4D* consortium, are related to the fields of art and culture. The analysis of the distribution of these case studies across various themes identified in the research provides an initial framework for understanding the field of immersive environments and technologies.

First of all, multidisciplinarity emerges as a significant concept highlighted by the observation of the actors involved in the design processes of immersive experiences. While various roles are evident across the case studies, the most prominent categories in the graph are those of designers and developers. It is important to note that these categories represent broader groups encompassing a variety of other professions related to design and development.

In the context of technology and device used, Virtual Reality and Augmented Reality are undoubtedly protagonists of current experimentations for immersive experiences, possibly obscuring other challenging but potentially rewarding modalities. Into VR field, most of the cases report the use of headset (e.g.: Meta Quest 2, others) and projection on walls. While using a visor provides users with a more precise and extensive range of controls and with a more defined graphic representation of the content displaced within the immersive environment, projectors enable intriguing experiments by eliminating the need for a device between users and the content of the experience. Several compelling case studies integrate projectors with body tracking systems or sensors and actuators capable of interacting with users. AR also constitutes a significant cluster in the observation of the technological field across the case studies. In this context, the displacement is facilitated by mobile devices that users manipulate within the tangible environment. The imperative to eliminate the device layer is particularly pronounced in this scenario, suggesting potential for intriguing solutions through future technological advancements.

From an interaction point of view, what can be observed is that a limited number of the collected case studies promote active interaction modalities, representing a potential gap for exploration. It is unsurprising that enhanced agency can lead to greater embodiment, engagement, and ultimately immersion (Witmer & Singer, 1998). Moreover, it seems that there are very few collaborative modalities between users in the case studies collected. Theoretically, literature often associates the concept of immersion with isolation (Turner *et al.*, 2016), but a sort of isolation from the concrete world in favour of the artifical environment could potentially be gained also with more people involved into the experience. This could be experienced with smoother and more elaborated technological systems than what we have nowadays. Interestingly, while senses play a fundamental role in fostering immersion (Biocca & Delanay, 1995), it is noteworthy that only sight and hearing are typically leveraged in immersive experiences. Most device clusters exhibit limitations in stimulating more than one or two senses, although exceptions are observed in specific installations where scent and/or tactile stimuli are incorporated. Some of the installations and experiences collected present to the users the possibility to involved not only the tradional human senses, but others such as umidity and temperature perception, mobility and proprioception; this inclusion of more senses than the traditional ones results into a more engaging and interesting case study. Future innovations in the technological sector may facilitate the development of immersive experiences that engage more than two senses without relying on complex installation setups.

The majority of the collected case studies feature animated content, referring to digitally produced videos and images; according to literature, animated content is known to enhance user engagement and focus (Tse, 2016; Amini *et al.*, 2018; Highsmith, 2021). This category of content enables creators to design immersive environments that are responsive and engaging, providing the opportunity to incorporate other experience characteristics such as narrative and playful elements, enhancing users engagement (Lochrie & Coulton, 2012; Boy, Detienne & Fekete, 2015; Deterding, 2016; Irshad & Perkis, 2020). Narrative elements are widely spread among the case studies, with some also including playful elements. However, personalization of the experience is less common, and a large group of case studies does not incorporate any of these engaging elements. The introduction of this elements into the experiences could lead to an enhancement of the embodiment, engagement and sense of presence of the users into the immersive environment.

The assessment method used to evaluate the most interesting case studies in relation to the Keys of Immersion has yielded several considerations. First of all, the subjectivity of the evaluation itself: the team tried to address this issue by addressed by involving a reasonable number of judges in the process. Additionally, it should be noted that none of the judges had firsthand experience with the case studies evaluated. Nevertheless, the researchers endeavored to assess the cases with a high degree of objectivity, drawing on their previous experience as researchers in the field.

However, it is interesting to observe the distribution of the case studies collected in relation to their degree of immersiveness.

The fourth quartile, considered the most interesting, is predominantly composed of VR experiences. The first one, *OVR Dark*, is a VR game delivered through headsets, characterized by a compelling narrative, emotional engagement, and gaming elements. The second one, *Anima Mundi*, is a projection experience hosted within an old church, where projectors display animated content intertwined with narrative elements, fostering augmented interaction between the virtual content and the physical elements of the building. The other experiences inside the quartile refer to museal installations enhancing the users experience of the artistic and cultural content, a virtual engaging projection of data visualization from Ars Electronica (*Data-Space*) and a promotional VR game. *Rain Room* (Random International) and *The Dreamachine* (Collective Act) stand out as artistic and research-oriented immersive installations, offering innovative ways to engage with immersive environments.

The case studies in the first quartile (those with the lowest scores) share a common characteristic of creating a perceived distance between the user and the immersive experience itself. This distancing effect takes various forms: some experiences rely on smartphones to guide the user, often drawing attention away from the immersive environment and towards the device itself (e.g., applications created to enhance cultural sites such as *Camp de Morvedre*, *Maestrat*, or the *Aljafería Palace*); others feature digital surfaces that respond to people's movements but do not present a meaningful experience (e.g., *The Eye of Mars*); and still others involve performers on stage, leaving the final users of the experience in the role of external observers rather than active participants (e.g., *The Hidden Music of Leonardo, Skin Awareness, Galileo all'Inferno*).

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5. Investigating the design process of immersive experiences in the cultural and artistic domain

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ABSTRACT

This chapter delves into a deep investigation of the design process involved in creating immersive experiences for the artistic and cultural domains. Specifically, it reports some of the activities and results produced by the research team from Politecnico di Milano as part of the *ARTCAST 4D* European project.
The complexity of the fragmented cultural and artistic sectors often makes it difficult to find public-specific information about the processes employed in designing immersive experiences, which proves challenging to investigate this aspect. Given these circumstances, the research aimed to conduct an in-depth exploration to investigate the occurring design processes by focusing on selected immersive experiences adopted as case studies.
At first, the previously collected case studies were evaluated with the aim of identifying those perceived as more immersive, creating a ranking drawing on the literature analysis. Then, among the experiences that emerged as most suitable, a further investigation was conducted by organizing semi-structured interviews with

professionals from companies that developed the experiences. Based on the availability, it became possible to deepen the analysis of five cases, among the ones identified as the most pertinent for the purpose of the study.
Each interview was guided by the researchers through the completion of online canvases in real-time, mainly aiming at mapping the design process and phases, the involved actors, the hardware and software, and the technologies and tools utilized for producing the immersive experience. Overall, it is interesting to observe how the outlined processes generally align with design-oriented methodologies, recalling phases of the Design Thinking model while incorporating additional phases more closely related to the technical implementation and delivery aspects. Furthermore, a common finding emerges in the collaboration between multidisciplinary professionals and in the presence of numerous iterations and experiments throughout various stages of the design process, which can be likely linked to the complexity associated with the general adoption of immersive technologies in these sectors.

5.1 Classification of the selected immersive experiences

Within the research context of the *ARTCAST 4D* European project, the study addresses the research question RQ3, which investigates *how immersive experiences are currently developed* in the artistic and cultural domains. The aim is to conduct an in-depth exploration to gain a comprehensive understanding of the design processes involved in the creation of immersive installations and experiences. Specifically, there seems to be a lack of a universally recognized and utilized design process for developing immersive experiences, and the complexity of the field poses challenges in conducting a thorough analysis, making it difficult to identify and examine the existing solutions.

The analysis of data from collected case studies revealed challenges in investigating deeper aspects related to elements such as the design process, the involvement of various actors at each stage of the system, and the specific project steps utilized. To overcome these challenges, a further step of analysis was initiated by adopting a different and more qualitative approach. This involved conducting semi-structured interviews on experiences across the case studies perceived as more immersive. Semi-structured interviews were deemed suitable for gathering insights and information not typically found in the public domain and, therefore, difficult to access.

As highlighted in the previous chapter, the selection of the most effective cases was based on evaluating each immersive experience using the Keys of Immersion derived from the literature analysis. This led to the identification of thirteen notable examples of immersive experiences, which were then classified based on specific characteristics. The classification considered the typology of technology and tools adopted, interaction modalities, and the field of application. Consequently, seven categories of immersive experiences emerged: VR video game, VR projection, VR interactive projection, VR HMD, Environmental installation leveraging sensors and actuators, Extended Reality XR, and Mind-based experience (defined by the uniqueness of one of the cases).

The thirteen case studies have been sorted following the category classification, and for each category, the ones with the highest immersion value were selected for organizing the semi-structured interview (Table 1).

The choice of reducing the case studies sample emerged to comply mainly with the time constraints related to the interview organization. Moreover, by addressing specific immersive experience categories, it has been possible to avoid collecting repetitive information.

After contacting the companies and professionals responsible for each case study production, it has been possible to conduct semi-structured interviews about the following five case studies:

- *OVRDark*, by QuasarDynamics (VR videogame);
- *Museo di Monte San Michele*, by Ikon (VR HMD);
- *Dataspace* - Deep Space 8k, by Ars Electronica FutureLab (VR projection);
- *The Dreamachine*, by Collective Act (Mind-based experience);
- *Collio XR*, by Ikon (Extended Reality).

Considering the case studies typology and the time constraints, it was not feasible to organize the interview about the *Environmental*

Category	Case study	Z score average
VR video games	OVR Dark	1,630353997
VR interactive projection	Anima Mundi	1,068468036
VR HMD	Museo di Monte San Michele	0,8437413786
	VR Workshop in Polimi	0,6662670129
	Nefertari Tumb	0,6369714561
	Mona Lisa VR	0,6035151725
	Nuii, VR adventure	0,5318550052
	Dreams of Dali	0,485945094
VR projection	Dataspace - Deep Space 8K	0,8339345419
	Borderless	0,7519289708
Mind-based experience	The Dreamachine	0,6219550155
Sensors and actuators	Rain Room	0,6150606896
XR	Collio XR	0,5329723834

Table 1.
Selected case studies divided by category.

installation only leveraging sensors and actuators category.
The next sections present a brief overview of the five experiences finally considered for the semi-structured interviews.

5.1.1 *OVRDark*, by QuasarDynamics

OVRDark (OVRDARK: a Do Not Open story, 2024) is a Virtual Reality horror game developed by a Valencia-based immersive video game company called Quasar Dynamics (Quasar Dynamics, n.d.). The VR game release is scheduled for March 2024. The game's engaging qualities are attributed to its escape room structure and the horror narrative, appealing to users on cognitive and emotional levels. Figure 1 gives a hint about the dark mood that the experience presents. *OVRDark* is a sequel to the game *Do Not Open*, a survival horror influenced by the mechanics of the escape room as well.

To fully enjoy *OVRDark*, users need familiarity with PlayStation VR tools and an interest in immersive gaming, particularly in horror-themed escape room narratives.
OVRDark employs tangible touchpoints such as the HMD and joysticks, enhancing the user experience regarding sight and hearing. Touch is further incorporated through joystick vibration, providing haptic feedback. Users interact with many virtual touchpoints, including typical video game elements and digital spaces. The game needs a focus shift and high engagement, inherent to gaming requirements and the horror escape room scenario intensifies cognitive and emotional involvement. The case study's application domain primarily lies within the gaming industry in the broader entertainment sector.

Figure 1. Representative image of the *OVRDark* experience. Courtesy of Quasar Dynamics.

5.1.2 *Museo di Monte San Michele* by Ikon

The *Museo di Monte San Michele* (Museo di Monte San Michele, 2018) is a museum dedicated to preserving memories and artifacts from the First World War battles on Monte San Michele, a significant war theater between the Italian and Austro-Hungarian armies. Situated in the Sagrado municipality of Friuli-Venezia Giulia, in northeastern Italy, the museum offers an immersive experience through various digital and interactive elements.

Visitors can explore the museum's outdoor path, scan QR codes on their smartphones to activate AR content related to historical places, and have a VR experience inside the museum, taken as the main focus of the case study analysis. Indeed, only the VR experience has been considered for both the categorization of the case study and the subsequent exploration through the interview. In the VR 360° room, fifteen HMDs enable visitors to watch 360° videos with audio, immersing themselves in key moments of the battle and an Italian pilot's flight (Figure 2).

Although the virtual position remains fixed, users engage emotionally and cognitively with real war stories, experiencing the content as viewers and listeners. Moreover, they can change their perspective and experience different content in the HMD by moving and rotating their heads.

The case study's focus is on cultural heritage, specifically pertaining to war history in the Gorizia territory, a prominent area for the Italian side during the First World War.

5.1.3 *Dataspace* – Deep Space 8K by Ars Electronica FutureLab

The *Dataspace* (Dataspace, n.d.) installation at Deep Space 8K in the Ars Electronica Center in Linz, Austria, stands out among various

Figure 2.
Virtual Reality experience at *Museo di Monte San Michele*. Courtesy of Ikon.

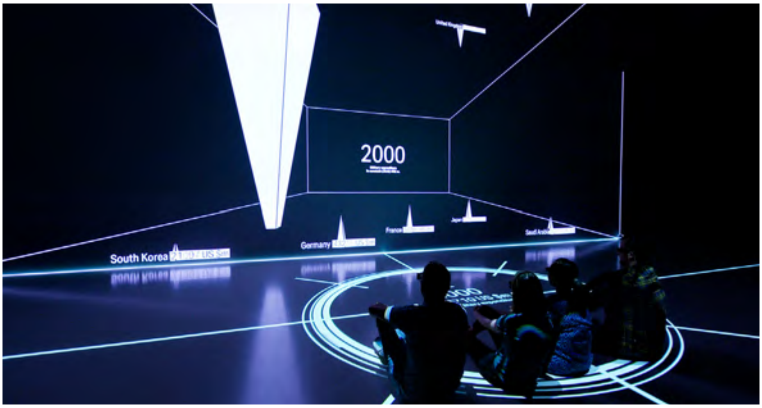


Figure 3.
Dataspace by Ars Electronica FutureLab. Image credits of Raphael Schaumburg-Lippe.

exhibitions as a compelling case study showcasing the capabilities of the space. Deep Space 8K (Deep Space 8K, n.d.) is equipped with advanced technological tools, including projectors, audio systems, and laser-tracking systems, serving as an immersive exhibition space for artists, studios, designers, and companies curated by the Ars Electronica Futurelab (Ars Electronica Futurelab, n.d.) team. Specifically, *Dataspace* uses this high-tech environment to project 3D visualizations of the deep impact of the ongoing conflict between Russia and Ukraine (Dataspace: Global Impact of Russia's War on Ukraine, 2022), as displayed in Figure 3. Visitors are immersed in a fact-based data space, providing a unique journalistic experience. *Dataspace* transforms media data into a different visual and interactive format, catering to a broad audience interested in the displayed content. This immersive installation captivates users with striking visual effects and encourages data reading, transitioning from traditional 2D screens or paper to immersive 3D projections. While users can move within the space, interaction with the content is limited. Sound enhances cognitive engagement. *Dataspace* serves as a case study exemplifying innovative approaches to interacting with media information within the context of immersive experiences for data visualization.

5.1.4 *The Dreamachine* by Collective Act

The Dreamachine consists of a unique interaction with light, first introduced by the artist-inventor Brion Gysin in 1959, reproposed and further developed by the Collective Act group. The immersive experience unfolds within a space where visitors recline, shut their eyes, and engage with various outcomes and visions facilitated by audio and light experiences. (About – Dreamachine, 2023).

The Dreamachine experience just uses light and sound patterns to create the immersive experience, that, within the confines of users' closed eyes, are shaped by mind and feelings. The experience allows the creation of an environment for collective contemplation and offers an enchanting insight into the everyday marvel of consciousness. During the experience, users are sitting reclined, with their eyes closed, while light and auditory stimuli are central to the experience (Figure 4). *The Dreamachine* caters to people curious to undergo the experience firsthand and researchers keen on scrutiniz-

Figure 4. ***The Dreamachine* immersive experience. Courtesy of Collective Act.**

ing user-reported results and impressions, encompassing scientific research, artistic expression, and entertainment.

5.1.5 *Collio XR* by Ikon

Collio XR (CollioXR, 2019) is a project by Ikon Company (Ikon, n.d.), designed to enhance the visitor experience in the Collio Goriziano territory in Friuli-Venezia Giulia, Italy. The primary focus of *Collio XR* is on cultural heritage, aiming to enhance the cultural and historical aspects of the territory. By emphasizing cultural and historical points of interest, the project provides users with an immersive and enriched experience, fostering a deeper connection with the landscape.

The project employs a mobile app, graphic totems, and VR experiences. The app provides sound content about walking paths, featuring facts and stories. Graphic totems offer AR content, displayed when scanned with mobile phones, allowing users to interact with the smartphone screen. The VR experience involves placing smartphones in cardboard glasses (Cardboard, n.d.) to trigger virtual content with the ability to enjoy 360° or 180° content by moving the head (Figure 5). Gamification elements, reward points, and badges are incorporated, and a geolocation system guides users during their walks.

Collio XR caters to users interested in landscapes and cultural enrichment, appealing to outdoor enthusiasts and those seeking immersive cultural experiences.

Figure 5.
***Collio XR* experience.**
Courtesy of Ikon.

5.2 Behind the immersive experience: interview structure and protocols

Starting by addressing the five experiences that emerged as most immersive, a further investigation was conducted by organizing semi-structured interviews with professionals from companies that developed the experiences. As previously mentioned, the semi-structured interviews have been organized to delve into qualitative aspects of information, mainly investigating the design processes adopted for creating each immersive experience. The interviews have been used to inquire information from a broad overview of the process to specific details, exploring also the actors involved and their roles, the hardware, software and tools employed during the experience production, and the interviewees' perspectives regarding the values and challenges encountered.

The interviews have been conducted online by following a precise structure and protocol: each aforementioned aspect has been mapped through the completion of five online canvases in real-time by using Figma (Figma, n.d.), a collaborative web application. The canvases served the dual purpose of visually presenting the topic of interest during the online interview and offering a space where abstract concepts exposed by the interviewee could manifest visibly, fostering conversation and understanding. Notably, two researchers of Politecnico di Milano, working on the *ARTCAST 4D* project, conducted the interviews: one engaged directly with the interviewees, and the other operated in the background to visually document the responses on the canvases, ensuring real-time visibility for the participant as well. Following, each canvas is explained in detail.

Canvas 1: addressing the overall process

The semi-structured interview was initiated by grasping a general overview of the design process underlying the case study and associating it with a visual representation. The discussion included four graphical representations of possible processes: linear, iterative, spiral, and highs and lows. Interviewees had the flexibility to choose one of the presented representations or to draw their own process freely on Figma. Subsequently, the selected representation was placed in the *working* *area* of the canvas, along with the start and end dates of the process, providing a clear timeline reference. The given graphical representations tried to propose the mostly adopted design processes: the linear design process, presents a straightforward structure with a sequential progression through defined phases, each building upon the previous one; the iterative design process, presents a circular, iterative structure, in which the whole sequential phases have been repeated for improvement; the spiral design process, presents continuous improvements and iterations based on repetitive phases, adapting to rapidly changing requirements and issues; the highs and lows design process, presents subsequential phases with periodic oscillations, occurring for smoothly adopting the structure to the requirements.

Canvas 2: specifying each step of the process

The subsequent step delved into a detailed exploration of each process phase, aiming to identify and comprehend the most significant steps. Circular shapes have been adopted to depict each phase of the design process by placing them on the previously selected or elaborated graphical path. In addition, each circle presented a customizable label to indicate the name of the process phase. This structure aided interviewees in recalling, reconstructing, and systematizing the process, facilitating articulating and describing the project's design and production. Indeed, each interviewee has been asked to freely give a name to each phase, based on her knowledge and experience.

Canvas 3: actors involved in each step

Then, the attention turned to the actors involved during the process. The canvas suggested a few macro categories of common actors, that could be recognized and selected. Moreover, additional roles could be pointed out and added by the interviewee. Actors were then assigned to the respective phases, and explanations about their roles were solicited, ensuring accuracy and completeness in capturing information. Specifically, the interviewee has been asked to indicate the role of each actor in the exact design phase by categorizing it as a technical actor, strategic actor, or recipient. Important emphasis has been given to technical actors, strictly connected with the tools and technologies adopted for creating the immersive experience.

Canvas 4: tools and technologies adopted

Progressing to a more detailed level, the interview explored the tools and technologies adopted to support the design process. Interviewees elaborated on software, hardware, or other means adopted by the identified actors across the different phases, by referring to their typology. The researchers mapped the mentioned tools in real-time directly on the process path under construction, categorizing them into three color-coded categories: software (yellow), hardware (pink), and design tools (green). In addition, the specific names of software and hardware employed have been specified, where possible, by adopting small white labels.

Canvas 5: values and challenges encountered

Concluding the interview, an overview of the defined design process has been adopted to remark on values and pain points encountered during the development project. This step facilitated a critical evaluation of the design process, identifying strengths and weaknesses contributing positively or posing challenges to the realization of the immersive experience. The values have been represented as green halos on the final process representation, while the challenges have been represented by using the red color instead.

5.3 Behind the immersive experience: addressing the professionals

After selecting the most immersive experiences and preparing the interview protocols, the research team contacted the companies responsible for the experience production. The semi-structured interviews involved various professional figures who played different roles in the design process of the selected case studies. Among them were game developer Anthony Leites Derossi and business developer Nicolas Terol, both affiliated with Quasar Dynamics, offering insights into *OVRDark*. Enrico Degrassi, the CEO of Ikon company, shared his perspectives on both *Museo di Monte San Michele* and *Collio XR*. Hideaki Ogawa, serving as the Director of Ars Electronica FutureLab and Director of Ars Electronica Japan, contributed valuable information related to *Dataspace*. Jennifer Crook, CEO and Art Director of Collective Act, brought her expertise to the table with insights into *The Dreamachine* project. These interviews effectively gathered firsthand information on specific aspects of the immersive experiences, investigating the design process, the key actors involved, the technologies and tools employed, and the main values and paint points of the process.

The following sections report the results deriving from the semi-structured interviews conducted with the professionals, divided by case study.

5.3.1 Quasar Dynamics – *OVRDark*

Anthony Leites Derossi and Nicolas Terol, both affiliated with Quasar Dynamics, have been interviewed on the *OVRDark* design process, which took place from mid-November 2022 to mid-July 2023.
The *OVRDark* case study employed a spiral design process, starting with an initial *Research* phase that underwent two iterations.
The research endeavors were conducted collaboratively by a researcher, a designer, a developer, and the CEO. Subsequently, a *Design game* phase ensued, delineating the effective output for the next *First experimentation* phase, involving developers and designers. The outcomes of this phase laid the groundwork for the *Development/production* phase, wherein developers and 3D artists actively engaged in crafting the video game. The *Marketing and sponsorship* stage encompassed the preparation of promotional and communication materials, alongside incorporating accessibility features, such as language translations.
An iterative *Testing* phase, comprising four to five checks with a beta-tester, contributed to the final adjustments to the game design.
Ultimately, the process concluded with the *Optimization* phase.
The contributors to the *OVRDark* design process included both internal and external actors. The CEO played a crucial role in strategic decisions, especially in the initial phases. A team of developers, led by one lead developer, along with 2/3 video game developers and a game designer, played pivotal roles throughout the process. Secondary roles with specific expertise were engaged as needed for particular phases, such as for marketing and testing. In the *Marketing and sponsorship* phase, external resources such as influencers, content

creators, streamers, a translator, a publisher, and a marketing/communication team member were essential. Most of the technologies and tools have been adopted in the *Development/production* stage and include software for 3D modeling, 3D animation, video game engines, texturing, rendering software, and sound production.
These tools have been essential mainly for producing video games and Virtual Reality content. In addition, a few devices have been adopted to present the final output and tested during the iterative *Testing* phase: the VR head-mounted displays Oculus and Pico and the PlayStation 5.

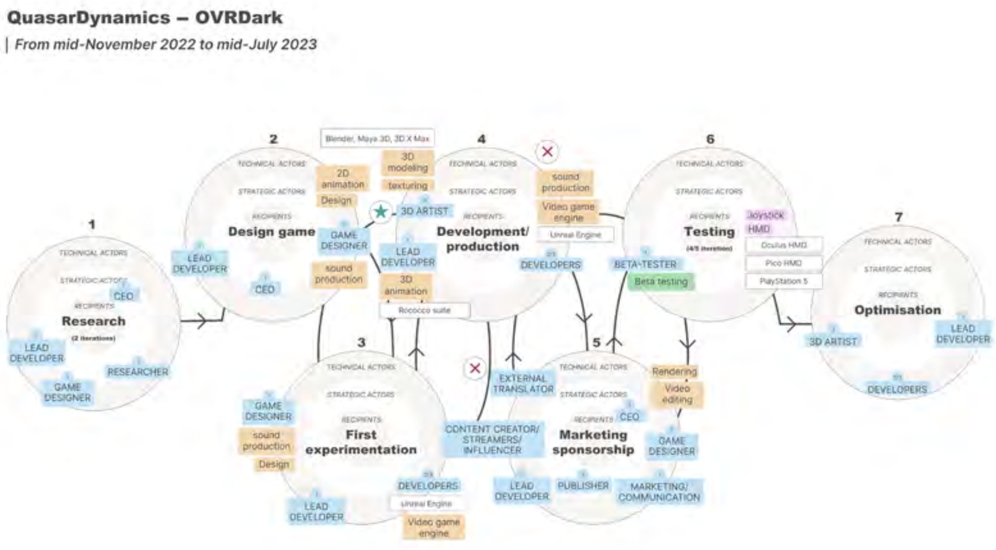


Figure 6.
Output of the interview process on *OVRDark*.

Considering the whole process, the primary value has been attributed to the contribution of 3D artists in the *Development/production* phase, while the main challenges have also been pointed out in the *Development/production* phase in relation to the necessity to adopt more actors, such as a sound designer, more 3D artists and more developers. Moreover, another pain point emerged from the need to translate the experience into many languages.

5.3.2 Ikon – *Museo di Monte San Michele*

Enrico Degrassi, CEO of Ikon, has been interviewed to deepen the investigation of the *Museo di Monte San Michele* case study, which was executed from March to October 2017. The interviewee associated the conducted design process with the spiral graphical representation, emphasizing the application of iterative phases and continuous challenges and improvements. Specific phases have occurred throughout the process, starting with *Brief*, in which internal and external actors addressed the project objectives, and leading to *Define* for strategic requirements. Then, *Design*, which was focused on user experience (UX), visitor flow, and technology, engaging experts, followed by *Historical research* and *Immersive production*, which focuses on the content creation and production by involving different professionals. Later, the iterative *Testing and refinements* phase includes beta testers and culminates in *Delivery*, with the deploying of the experience. Different actors played an important role during each phase of the process, with key roles of CEO/Creative Director and project manager, which have been associated with almost every phase of the process. External stakeholders like Fondazione Carigo (Fondazione Carigo, n.d.) and Intesa San Paolo Bank (Persone E Famiglie, n.d.) commission the project, and the Sagrado (Comune Sagrado, n.d.) municipality and Onor Caduti (Ufficio per La Tutela Della Cultura E Della Memoria Della Difesa – Difesa.it, n.d.) association contribute to the redesign process of the Museo di Monte San Michele as well. Essential technical actors include visual effects experts, 3D artists, light designers, camera operators, and sound engineers. In addition, the testing phase involved a museum operator and a team of 10/15 users, and the delivery phase included the project stakeholders, museum curator, electrician, and system manager. Moreover, the project required diverse technological competencies and tools, including VR content creation, specialized shooting techniques, post-production software, 3D modeling, and VR engine software for animations. The *Immersive production* phase, involving many actors and presenting many aspects to deal with, has been pointed out as the most challenging one.

5.3.3 Ars Electronica FutureLab – Dataspace at Deep Space 8k

Hideaki Ogawa, Director of Ars Electronica FutureLab and Director of Ars Electronica Japan has been interviewed to investigate the process adopted for designing and producing the *Dataspace* experience, which has lasted from September 2021 to September 2022.

This case study employed an iterative approach, featuring the circular graphic representation. The process started with an *Inspiration* (*creative compass*) phase, followed by a *Question* (*future vision*) phase involving both external and internal actors. These included the media company collaborators, the project manager, the CEO of Ars Electronica FutureLab, the art director, a curator, a strategic developer, and a researcher. This phase included the brief and concept iteration, employing workshops organization and the use of online UX design tools to define the outputs. Subsequently, the *Research and development* phase allowed to get into the realization of the experience, involving developers, designers, and a content management team.
The *Prototype* (*production*) phase showcased final outcomes with the same developer and designer teams. The *Dialogue* (*testing*) phase subjected the outputs to iterations with questionnaires, confirming the quality of the final immersive experience produced.

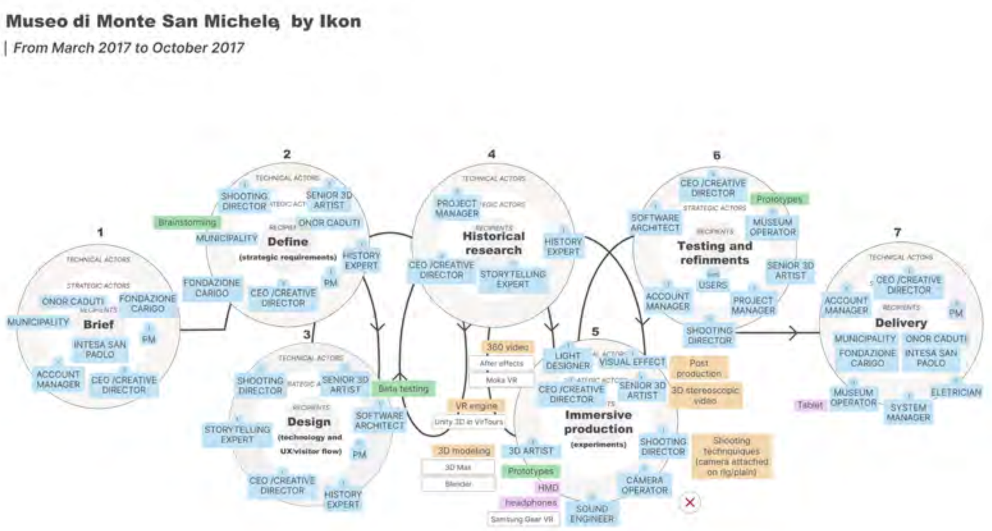


Figure 7. Output of the interview process on *Museo di Monte San Michele*.

The overall process highlighted a strong management team presence, with visual designers and researchers involved in every phase alongside managers. In addition, a representative media company followed the entire process. In the initial phases, a curator and strategic developer were present as well, while a producer participated just in the *Inspiration* (*creative compass*) session. In the *Research and* *development* phase, have been introduced actors presenting more specific technical skills like a sound designer, a software developer, and a visual developer, along with two visual designers and a content management team. In the *Prototype* (*production*) phase, a strategic team has also supported the aforementioned technical roles. A communicator figure was added in the *Dialogue* (*testing*) step.

The immersive experience contents, which are presented to the users through wall projectors, have been produced using different software. Graphic production, video editing, game engine, and sound production software were employed to design and develop the experience. Considering the whole process, the first and the last phases of the process, named *Inspiration* (*creative compass*) and *Dialogue* (*testing*) were recognized as the most valuable, while challenges included balancing data and visual effects and representing the simulation into reality.

5.3.4 Collective Act – The Dreamachine

Jennifer Crook, the CEO and Art Director of the Collective Act, has been interviewed on the design process of *The Dreamachine* project, which she started before constituting the consortium, in November 2020 and that ended in May 2022. Gradually, numerous external collaborators and financial backers were engaged in this span of time, expanding the collective responsible for the immersive installation.

The first phase of the process has been identified as *Research and Development*, lasting three months and featuring Crook as the director, alongside a sound designer, a scientific specialist, an architect, and an engineer. This group laid the groundwork for the design process and gathered ideas for validation in the subsequent *Proof of Concept* phase. Here, the team grew, delivering the output to the commission in the following step, known as the *Commission* phase. A *Budget and Feasibility* phase ensued to verify the overall design concept, in which the production teams started the production until reaching the *Prototyping* phase, in which a total of four prototypes were produced, involving numerous actors who participated in focus group sessions. The *Developing* phase progressed towards final validation and comprehensive experience development, culminating in the *Delivery*. *The Dreamachine* engaged a substantial number

Dataspace — Deep Space 8k, by Ars Electronica FutureLab

| *From September 2021 to September 2022*

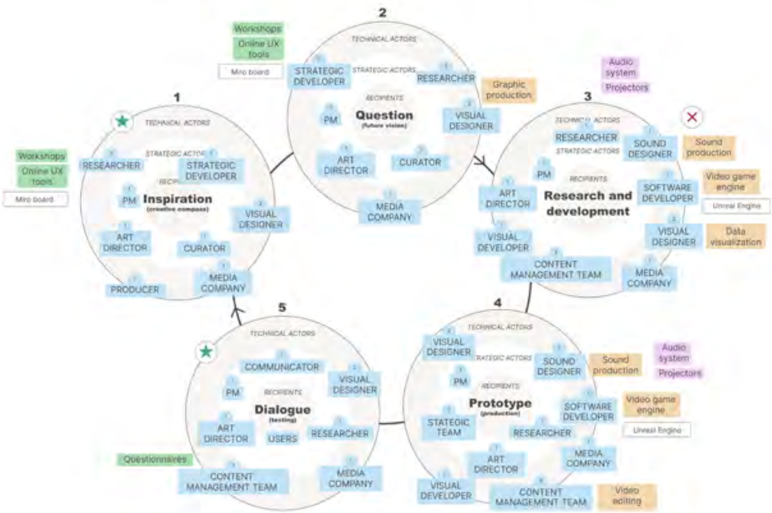


Figure 8. Output of the interview process on *Dataspace*.

of professionals. from the project's early stages. The *Research and Development* phase included the project director, an engineer, a sound designer, a composer/artist (Jon Hopkins), and a team of three architects and three researchers from scientific fields. Step-by-step funding allowed the team to grow, totaling 18 individuals with production and organizational roles during the *Proof of Concept* phase. In the subsequent *Commission* phase, several local partners, ranging from three to 20, were also incorporated. The *Budget and Feasibility* phase required the addition of four to five researchers, a marketing and communication team (consisting of one to five actors), two lighting designers, a production team of five, and the continued presence of previously engaged roles. This constituted the team that guided, designed, and developed *The Dreamachine* experience until the *Delivery* phase. The software used during the production of *The Dreamachine* includes those for managing light pattern movements and sound. Other software, such as 3D modeling and rendering tools, were also mentioned mainly in relation to materials produced for strategic pitches. Considering the overall design process, the stages identified as the most valuable were the *Research and Development*, *Prototyping*, and *Delivery* phases, while challenges primarily revolved around time and financial resources allocated to the *Budget and Feasibility* and *Development* phases.

5.3.5 Ikon – Collio XR

Collio XR is the second project on which Enrico Degrassi, the CEO of Ikon company, has been interviewed. The design process for creating this immersive experience spanned from mid-2018 to spring 2019 and presented some differences in regard to *normal procedures* of the company, due mainly to the peculiarity of the context of the experience. Indeed, this project also followed a spiral pattern, as for the *Museo di Monte San Michele*, yet presents some ramifications and distinctive features.

The design process began with a *Brainstorming/Concept* phase, where the commission of external stakeholders engaged with Ikon's CEO, CTO, UX specialist, project manager, and storytelling expert. Together, they delineated project needs and requirements. The process was bifurcated from the first phase, and two parallel processes emerged, presenting both a spiral evolution: one dedicated to developing the mobile app and AR/VR contents, and the other focused on crafting cultural and historical content. The first stream involved stages like *UX design*, *Proof of concept and Development*, *Testing*, and

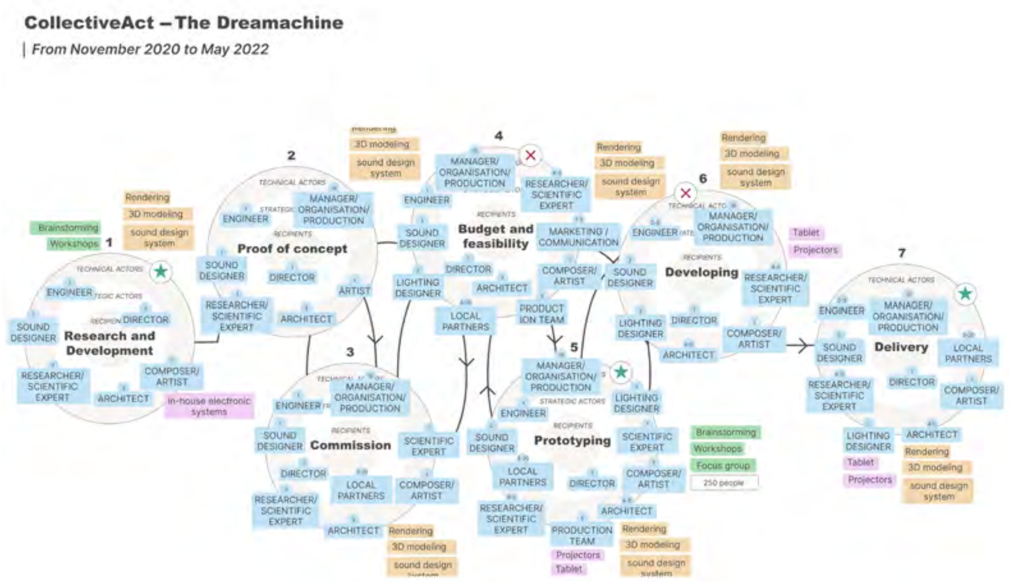


Figure 9.
Output of the interview process on *The Dreamachine*.

Development. In this path emerges the presence of recurring actors such as a UI designer, a back-end developer, and a mobile application developer. In addition, the *UX design* phase is characterized by the presence of the storytelling expert and a UX expert, the *Testing* phase saw the involvement of 8 alfa-testers, while in the *Development* stage, an XR developed was included.

The second path comprised phases such as *Historical research*, *Storytelling narrative*, and *Multimedia content production*. Here, a storytelling expert played an important role in the initial stages, supported by humanities experts and a screenwriter, while the last step saw the engagement of a video producer/postproduction expert, art director, and three 3D designers.

Both paths converged in the *Integration/Data entry* phase, where the historical and cultural contents have been integrated within the mobile app, VR, and AR components. The final stage, an iterative *Testing and delivery* phase, culminated in the project's ultimate outcome.

Throughout these parallel dimensions, the CEO, CTO, PM, and external stakeholders provided oversight. The *Integration* phase saw two data-entry professionals bridging the content and technological dimensions, while external association members specializing in culture and sport were recruited for testing the final outcome during the *Testing and delivery* phase.

Collio XR comprises a mobile application offering VR and AR content experiences. The mobile app was crafted through coding, UX, and game engine software, with graphic content generated using Adobe Creative Cloud Suite programs. AR and VR content has been developed by using a 3D modeling software, an Insta360 camera for capturing 360° video content and implemented using a video game engine.

The challenges encountered during the design process were spotted in the *Testing* phase, especially when tests were conducted outdoors on the field.

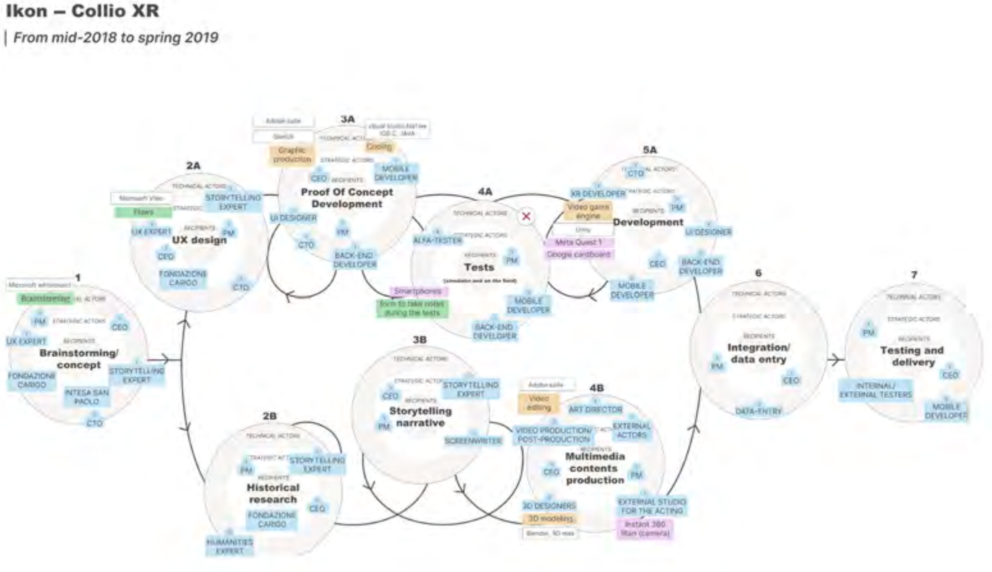
5.4 Discussion of the results

The data acquired through semi-structured interviews were then analyzed and compared to address the differences and similarities among the case studies. Thanks to the adoption of online canvases compiled during the interview process, the information was extracted and analyzed in an easy way, leading to the consideration that the qualitative method and the protocol adopted were successful. The challenge of defining design processes, actors, technologies and tools was effectively met with the guided conversation between researchers and interviewees.

5.4.1 Addressing the design process and phases

The prevalent graphical representation selected to outline the process adopted was the spiral one, with the exception of the *Dataspace* experience, in which the circular, iterative process was followed. This aspect reinforces the idea of the complexity of producing an immersive experience in the artistic and cultural sector, influenced by the distinctive design challenges involving innovative technologies that exclude processes such as the linear one. Indeed, taking into account the different aspects of immersive technologies, encom-

Figure 10.
Output of the interview process on *CollioXR*.



passing, for example, sensory stimulation and interaction modalities, multiple rounds of internal and external testing, validation, and engagement with multiple actors seem necessary before reaching the final experience outcome. Consequently, the iterative model was selected as the most fitting depiction of the design process. Notably, in the *Collio XR* process, the spiral model has also been followed, yet presenting two parallel spiral paths, in which the focus is on the content production and the technological aspects, respectively. This aspect can be connected with *Collio XR* being the only project addressing Extended Reality among the selected cases, encompassing both VR and AR technologies. Moreover, this specific experience is thought to occur outdoors, presenting several challenges compared to a defined indoor environment.

As mentioned, instead, the case of *Dataspace* deviated from the group by opting for a fully iterative circular representation, yet iterations of various forms are evident in this design process as well.

Considering the duration of the processes, the one that presented a longer development is *The Dreamachine*, which started in November 2020 and was completed in May 2022, while the other processes lasted approximately less than one year.

Most of the design processes present seven phases. Some phases, such as *Research and Development*, are recurring and are positioned as the third and first stages in *Dataspace* and *The Dreamachine*, respectively. Similar research phases are also identified at the beginning of *OVRDark*, which features an initial *Research* presenting two iterations. In contrast, the research takes on a more specific connotation in both the *Museo di Monte San Michele* and *Collio XR*, where it is labeled as *Historical Research*, specifically referring to the contents displayed during the immersive experiences. Other recurring phases include the *Design*, which is positioned as the third stage for the *Museo di Monte San Michele,* while it appears as the second phase with the labels *Design Game* and *UX Design* in *OVRDark* and *Collio XR*. In *The Dreamachine* case study, the design phase is referred to as *Proof of Concept*.

Additionally, there is a recurring presence of a prototyping phase called *Prototype* and *Prototyping* in *Dataspace* and *The Dreamachine*, and *First Experimentation* for *OVRDark*, along with *Proof of Concept De-*

velopment in *Collio XR*. Furthermore, most of the processes, exceptions made for *The Dreamachine,* also include a *Test* stage, often associated with a *Development/Production* and a *Delivery* phase.

A noteworthy observation pertains to aligning the processes that emerged with common approaches to design and innovation, such as Design Thinking (Dam & Siang, 2021) and Double Diamond (Kochanowska, 2022) models. Indeed, both models place emphasis on aspects of divergence (openness to different perspectives and generation of ideas) followed by convergence steps (selection and implementation of the best ideas), presenting an iterative nature.

Initially introduced by the d.school at Stanford's Hasso Plattner Institute of Design (Hasso *et al*., 2009), the Design Thinking methodology has permeated various fields, embodying user-centered, iterative design principles. The traditional process unfolds in five stages, *Empathize*, *Define*, *Ideate*, *Prototype*, and *Test*, offering flexibility in their sequence, concurrent execution, or repetition.

The *Empathize* phase is centered on research to adopt an emphatic understanding of the problem and to deeply comprehend the users' needs, usually by directly involving the final users in the process. This aspect, related to the user research, did not explicitly emerge in the initial stages of the discussed projects. However, diverse perspectives and opinions were integrated from the outset. For instance, Ikon Company adopted a participatory approach, involving stakeholders in problem framing, while Ars Electronica FutureLab and Collective Act engaged various professionals from the project's beginning. In addition, in most of the cases, the research on historical contents and technological means allowed professionals to gain an understanding of the context and the problem to address.

The *Define* stage, a synthesis of insights from preliminary research into framing the design problem, proved indispensable. In specific cases, such as *Museo di Monte San Michele* and *Dataspace*, this was recognized as a distinct phase named *Define* and *Question/Future vision*, respectively. In others, interviewees reduced its significance, describing a direct transition to the *Ideate* phase, where initial research informed the generation of ideas and experimentations. In this step, innovative solutions are presented to respond to the problem statement previously defined.

The subsequent phases, involving the development of ideas, revealed a clear analogy with the *Prototype* and *Test* stages of the Design Thinking process across all examples. Addressing technical, financial, and communicative aspects, the experimental nature of immersive technology projects surfaced prominently, leading to a highly iterative process.

While the Design Thinking flexibility aligns well with the analyzed case studies, a supplementary stage such as *Implement*, proposed by Nielsen Norman Group (Gibbons, 2016), can be essential for completion. Acknowledging the tangible production of immersive experiences, references to stages like *Development* or *Production* recurred in the examples. This stage has also been recognized as the most challenging in most of the case studies by reinforcing the perceived complexity of dealing with immersive technologies and tools, for realizing the design ideas. In addition, a further step named *Delivery* appears in a few projects as the final achievement of the immersive experience, marking the conclusion of iterative cycles.

5.4.2 Framing the actors and technologies-tools

The interviews generally outline various professional roles involved in the design processes. From the initial stages onward, various actors, whether internal or external to the organization, participated in the projects. The collaboration of multiple experts enriches the process, ranging from technical actors and researchers to marketers and creatives. Technical figures play a prominent role, but their distinctive specializations align with the immersive experience's complexity and characteristics. Indeed, dealing with immersive technologies necessitates the allocation of distinct tasks that can be encountered transversally within the cases, such as programming, 3D modeling, light design, sound design, etc., ensuring successful outcomes. However, the significance of technical skills lies in their collaboration with diverse actors, including scientific experts, researchers, and various creatives, being more focused on the content addressed by the immersive experience. Notably, it is observed that the team becomes increasingly multidisciplinary as the immersive experience grows in ambition, implying a high collaboration among different actors.
Concerning the target audience, the analyzed experiences did not

address a specific typology of users, yet aiming for accessibility across genders, ages, cultures, educational backgrounds, and languages.

Nonetheless, it is worth mentioning that in most cases, the typology of immersive experience seems crucial in attracting a specific target audience: *OVRDark* targets users familiar with HMDs and horror games; *Dataspace* appeals to those exploring media data and data visualization, *The Dreamachine* attracts users curious about experimental mental processes, while *Museo di Monte San Michele* and *Collio XR* cater to users interested in cultural heritage.

Pertaining to the immersive technologies encountered in the case studies, they encompass both AR and VR delivered by using devices such as HMD, projections, light, and sound systems. Among the HMD, different typologies emerge such as Samsung Gear VR, Oculus VR, and Pico VR. Even seemingly traditional technologies, like light and sound systems, as seen in *The Dreamachine*, offer innovative user immersion experiences, stimulating users to undergo a mind-based experience. Throughout the interviews, different software and design tools emerged as relevant in designing and developing the immersive experiences. 3D modeling (Blender, Maya 3D, 3DMax), rendering, animation, video editing (Adobe Suite), sound and graphic production (Sketch), and game engine (Unreal Engine, Unity 3D) software consistently appear in most of the processes. These varied and diversified tools underline the trends and complexity that lie beneath the development of specific technical skills for immersive experience production. Furthermore, different design techniques and tools emerged, especially in the initial stages of the processes, such as brainstorming, workshops, and online UX design tools (Miro board).

5.4.3 Overall limitations and findings

In the landscape of immersive experiences for the artistic and cultural domain, it is evident that the investigated cases cannot be statistically representative of broad generalizations. Even if the limitations in number, collection, and selection methods, along with the contextual nature of the projects, it is well recognized, the analysis of interview results has revealed interesting insights. A common thread in all the experiences is the introduction of immersive technologies to bring a conventional experience to a higher level. *OVRDark* emphasizes engagement as a key characteristic in the video game sector, enhancing user immersion through VR. *Dataspace* uses immersive environments to enhance user connection with media data, augmenting activities like news reading and information acquisition. Similarly, *Collio XR* and *Museo di Monte San Michele* employ immersive technologies like AR and VR to offer enriched landscape experiences and cultural engagement. In *The Dreamachine,* immersive technology is used to enrich the exploration of the human mind's potential.

Furthermore, it can be generally noticed that several aspects during the design process need to be taken into account to obtain high-quality experiences. Indeed, it is noteworthy to mention that due to the complexity of immersive technologies, the quality of the final experience is not solely dependent on the final device adopted, such as the HMD or smartphone; emotionally engaging content, overall UX, meticulous details in video and animation design, and production contribute significantly to the final outcome.

Considering design processes, the selected examples, despite some variations, adhere to a design-oriented methodology involving phases like *Research*, *Design*, *Prototype*, *Test*, *Development*, and *Delivery*. The involvement of external stakeholders typically occurs during the initial and final stages of the process, with an iterative nature recognized within each phase of the process, associated with a spiral model. The results also highlight a remarkable interdisciplinarity among actors, depending on project objectives, technologies, and desired outcomes. A diverse range of expertise is harnessed, from CEOs to researchers, designers to developers, and historical experts to technical specialists. A key role is covered by UX designers, developers, game engine developers, 3D artists, or other technical roles strictly related to the technological needs of the project. The richer and more multidisciplinary the team is, the more diverse and original the immersive experience can be.

Across the cases, VR, experienced through HMD, results as a prevalent element, which necessitates precise software and tools to deal with the challenges and variety of the production: 3D modeling, rendering, animation, and game engine software appear as the most adopted. In conclusion, although some common elements can be identified across the analyzed immersive experiences in terms of adopted processes and phases, involved actors, utilized technologies, and tools, each experience exhibits diverse and specific characteristics primarily associated with the project's objectives, content, and contextual factors.

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6. Bridging technological and cultural realms: a holistic framework for analysing user perspective in immersive experiences

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[3]IFAAR

ABSTRACT

This chapter aims to provide a holistic understanding of immersive technology from a user perspective by recognising the synergies of the interrelation between technology and culture. Existing frameworks for designing and assessing immersive experiences often focus predominantly on the technology components, overlooking the role of content within the overall experience. However, this approach does not take into account the symbolic, subjective and intrinsic value of content, a fundamental component in cultural experiences. Cultural experiences shape feelings, perceptions, values, and identities through the contents presented in the experience. Therefore, the integration of immersive technology into cultural experiences requires an approach that captures the effects of the experience on the user in a comprehensive manner. Incorporating these elements into the design and analysis of immersive experiences is crucial to understanding the profound effects such experiences exert on individuals. In the context of the *ARTCAST 4D* project, empirical research into users' online de-

mand for immersive experiences across various channels unveils a nuanced preference for encounters that prioritize emotional resonance and cultural depth. This user-centric perspective sheds light on the intricate interplay between technological interaction and cultural content consumption, offering valuable insights into evolving user preferences in immersive experiences.

6.1 Introduction

The rapid advance of immersive technologies has opened up a new era of experiential possibilities, transforming the landscape of a wide spectre of domains, including culture. Immersive technologies are predicted to have a profound influence on culture due to their extensive use for marketing, accessibility or heritage preservation purposes (Guttentag, 2010; Beck *et al.*, 2019), as well as for new product developments if articulated with other elements to stage meaningful and memorable experiences (Pine & Gilmore, 1998; Stamboulis & Skayannis, 2003; Ellis & Rossman, 2008).

The immersive and interactive capabilities of these technologies have proven to be key in presenting culture to the public and enhance the visitor experience (Carrozzino & Bergamasco, 2010; Jung *et al.*, 2016; Dieck & Jung, 2017). Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) now play a fundamental role in the way people perceive, consume and learn about cultural phenomena, offering the trend of ever immersive, engaging experiences (Dieck *et al.*, 2021). The immersive nature of these technologies allows users to engage with culture in an interactive and immersive way, generating greater user involvement.

While the application of immersive technologies has unlocked a vast array of possibilities, the current paradigms of immersive experience design oftentimes do not fully exploit this potential, due to their technology-centric perspective. Many existing frameworks emphasise primarily the technological aspects of immersive and interactive encounters. As a result, evaluation criteria for immersive experiences tend to revolve around technical parameters describing usability and accessibility, relegating content aspects to a secondary role.

In the cultural domain, the richness of immersive and interactive experiences is not only determined by the sophistication of the technology employed, but also by the quality and meaning of the contents presented in the immersive environments. While technology sparks curiosity due to its novelty, content is usually the main reason why an individual engages in a cultural activity (Manolika & Baltzis, 2020), hence the significance of addressing the characteristics of content and its impact on the user in the design of immersive experiences. This decoupling between technological and content focuses highlights an urgent need for a paradigm shift in the understanding of immersive experiences. Strengthening the significance of the content aspects and its impact on cultural facet of immersive experience will allow for a better integration, enabling the creation of even more meaningful immersive experiences.

Along this chapter, the authors will discuss the current paradigm for the design of immersive experiences and subsequently highlight the role of content in cultural experiences and its impact on individuals participating in them. The chapter also exerts some empirical evidence of content-oriented immersive experience from the user perspective through an online survey of digital impacts of relevant keywords regarding immersive experience across different channels including search engines and social media. The survey results provide insights into the complex dynamics between technological engagement and cultural content consumption in immersive experiences, highlighting the evolving trends in user interactions.

6.2 Immersive technology and immersive experiences

6.2.1 Immersive technology in the cultural domain

Immersive technology is a broad term that encompasses any technology providing a computer-generated simulation of reality with physical, spatial and visual dimensions, blurring the line between the real and virtual worlds, allowing users to feel fully involved in the experience (Lee *et al.*, 2013; Tang *et al.*, 2022). The current literature relates immersive technology with the sense of being involved in a simulated or synthetic environment, thus viewing them as VR spin-offs (Di Serio *et al.*, 2013; Yung & Khoo-Lattimore, 2017; Suh & Prophet, 2018).

The concept of *immersion*, which fundamentally shapes the understanding of immersive technology, has been a topic of discussion and utilization among technology researchers for decades. Recent literature conceives immersion as a state of mind in which a user is deeply engaged within an immersive environment (Sherman & Craig, 2018). The term is frequently employed in the context of VR and software, where there are different views regarding its definition, depending on whether they consider immersion as a feature of the technology or as a subjective experience of the user (Suh & Prophet, 2018; Tang *et al.*, 2022). Early scholars in the VR field introduced immersion as a technical concept describing the objective features of technology (Slater & Wilbur, 1997). However, recent studies conceived immersion as a phenomenon experienced by individuals as a result of their mental involvement in a task (Georgiou & Kyza, 2017; Agrawal *et al.*, 2020). This perspective is rooted in the conceptualization of immersion as a metaphorical term, drawn from the tangible experience of being submerged in water (Murray, 2017), to describe the mental state of individuals when engrossed in narrative content (Ryan, 2001). Thus, immersion can also be achieved without the mediation of technology (McMahan, 2003). In this context, immersion can be seen as a form of cognitive and emotional absorption, which has been asserted to promote enjoyment, engagement in tasks and even facilitating learning (Georgiou & Kyza, 2017).

As this chapter does not aim to delve into the ongoing debate, it can be assumed that immersive technology anticipates an experience mediated by technology that transports the user into a digital environment. At its core, immersive technologies seek to transcend traditional boundaries of user interaction by providing an engaging experience. Key features of immersive technology include high interactivity, often facilitated through advanced input devices, and profound sensory involvement, leveraging technologies such as VR and AR to create a multi-sensory experience. The use of immersive technology has expanded across various fields due to its ability to offer the user a novel way of consuming content characterized by interactivity and the prominent role of technology as a medium or catalyst for the experience (Nilsson *et al*., 2016; Agrawal *et al*., 2020).

In the cultural domain, immersive technology has brought about a transformative shift in how visitors interact with heritage and engage with cultural content., due to its potential to attract a broader audience and enhance visitor experience (Jung *et al*., 2016; Dieck & Jung, 2017; Bekele & Champion, 2019). Advancements in aspects such as rendering, computer graphics, device interoperability, and the integration of Artificial Intelligence into technologies like VR and AR has led to the development of increasingly impactful immersive experiences. While these advancements have unlocked new possibilities for cultural consumption, understanding its true impact requires an exploration of user's subjective experience (Li *et al*., 2023).

6.2.2 User Experience design in immersive technology

Given the growing synergy between technology and culture (Li & Bacete, 2022), it is essential to comprehend how the adoption of immersive and interactive technologies impacts cultural experiences from both technological and user standpoints. From a technology viewpoint, current efforts are directed towards creating and using more affordable, simpler, environmentally sustainable, and easy to use devices as possible (Carrozzino & Bergamasco, 2010). The aim is to overcome barriers preventing from a broader use of these technologies (Dieck & Jung, 2017). From a user viewpoint, the research has focused on users' physical, cognitive and affective response to immersive technologies, with particular emphasis on behavioural intention (Huang & Liao, 2015; Pletz, 2021; tom Dieck *et al*., 2021).

Crafting immersive experiences necessitates careful consideration of various facets pertaining to both technology and users, all of which are encapsulated within the principles of User Experience (UX) design. The ISO 9241-210 standard defines user experience as a person's «perceptions and responses that result from the use and/or anticipated use of a system, product or service». Thus, UX is a multidimensional construct that encompasses diverse criteria, ranging from pragmatic aspects to hedonic attributes that are linked to usability and experience goals (Hinderks, Schrepp, *et al*., 2019). These criteria extend to the effects of technology on user satisfaction, emphasising the importance of technical functionality, ease of use, and performance (Hinderks, Winter, *et al*., 2019; Lewis & Sauro, 2021). In this sense, the focus of UX on examining user's cognitive and affective reactions is primarily geared towards understanding the role of emotions as antecedents, consequences and mediators of technology use (Hassenzahl & Tractinsky, 2006, p. 93).

In the realm of immersive technology, UX considerations frequently revolve around the concepts like presence, embodiment, and other constructs critical for achieving immersion, alongside common aspects such as engagement, enjoyment and novelty (Kim *et al*., 2020; Konstantakis & Caridakis, 2020; Oprean & Balakrishnan, 2020). Kim *et al.* (2020) classified the characteristics affecting user experience components in VR, depending on user attributes device attributes, and types of activities performed by users, also including evaluation criteria. Konstantakis and Caridakis (2020) examined the application of UX design in technology applied to cultural heritage, emphasizing the role of technology in enhancing user satisfaction within cultural experiences.

While these considerations are key in achieving user satisfaction and engagement in immersive experiences, a predominant bias towards technology aspects must be acknowledged. Immersion is a complex construct that depends on both technological and content aspects. However, the role of content in immersive technology has been historically neglected, only serving as the framework within which the experience takes place and the guiding thread that invites the user to interact (Slater & Wilbur, 1997). Indeed, content serves as a narrative thread that facilitates interaction, yet the intrinsic value of content can generate effects on the user that have not been considered in isolation. In other words, the intrinsic attributes of content can exert influence on the user's perception, having an impact on users' affective and cognitive response, in addition to those reactions elicited by the utilisation of technology. Therefore, the predominant focus on technology in UX design for immersive experiences leaves a critical gap in understanding the role of content in immersive technology experiences.

6.3 Cultural Experiences and immersive technology

Immersive experiences in cultural and creative sectors go far beyond mere technological engagement; they evolve into intricate cultural interactions. The convergence of technology and culture generates a profound symbiosis, where immersive encounters not only captivate the senses but also weave a narrative deeply rooted in symbolic content. These experiences offer participants a journey intertwined with cultural narratives, whether they be virtual museum exhibits, educational simulations, or interactive narratives.

The immersive experience integrated into the cultural context remains a cultural phenomenon and should be treated as such. In acknowledging its integration with cultural elements, it becomes imperative to approach it within the broader framework of cultural encounters. Recognizing the symbiosis between immersive technology and cultural context ensures a more nuanced understanding of its impact on individuals within the cultural landscape. Therefore, the resulting experience is not merely a technological engagement but a cultural phenomenon that necessitates a holistic and culturally informed approach for a comprehensive understanding.

To fully grasp the user's perspective within the realm of immersive experiences, it is essential to delve deeply into the characteristics of cultural experiences.

6.3.1 Characteristics of cultural experiences

The cultural experience encompasses a multifaceted realm, intertwining symbolic, intrinsic and subjective dimensions that collectively contribute to its profound value.

Beyond its tangible aspects, such as attendance or participation, cultural experiences carry profound symbolic significance. They serve as vessels of meaning, capable of representing and communicating complex ideas, values, and emotions (Colbert & St-James, 2014). Exhibits, performances, and interactive narratives become symbolic representations of historical events, cultural heritage, societal values, and artistic expressions. The symbolic value lies in their ability to encapsulate and convey profound messages, often sparking reflection and dialogue among participants. These experiences become powerful symbols that vibrate with individuals on a symbolic and cultural level, creating a shared language.

The intrinsic value lies in the unique qualities that define cultural encounters, encompassing their ability to inspire, educate, entertain and evoke a range of emotions. It encompasses the intellectual, aesthetic, spiritual, and emotional dimensions, highlighting the transformative power of art in enriching the human experience (Holden, 2006).

Therefore, cultural experiences bring about changes in their visitor (Soren, 2009). Individuals can transform their experiences into knowledge, skills, attitudes, values, emotions, beliefs, and relations. Through cultural experience individuals learn to understand and reshape the codes that underlie cultural meaning. Rausell-Köster *et al.* (2022) define the concept of *cultural experience* as:

> **the generation, emission or reception of information flows with symbolic content, usually expressed through artistic grammars, that have the explicit and more or less deliberate intention of having some kind of resonance on our cognitive, emotional or aesthetic dimension or our perception of our location in a social body (Rausell-Köster *et al.*, 2022, p. 2).**

In this context, the authors apply the concept of resonance, as articulated by the German philosopher and sociologist Herman Rosa (cited in Bialakowsky, 2018). Resonance stands in opposition to alienation and possesses four key characteristics. Firstly, resonance occurs when one feels affected by something. Secondly, the subject reacts to this influence, reflecting the psychological concept of self-efficacy. Thirdly, the experience has a transformative capacity of varying intensity and duration. Finally, resonance is elusive and cannot be approached instrumentally, making it unpredictable even in a controlled context (Susen, 2020).

The subjective dimension adds another layer to the complexity, highlighting that the worth of a cultural experience is inherently personal and varies significantly among individuals. This variability is influenced by factors such as perspectives, background, and emotional responses (Stylianou-Lambert, 2010). In the context of cultural engagement, the subjective dimension recognizes that individuals bring their own set of beliefs, values, and life experiences to the table. This diversity of personal context profoundly influences how an individual interprets, appreciates, and internalises the cultural content presented. For example, two people attending the same museum exhibit may derive entirely different meanings based on their subjective experiences, interests, and cultural backgrounds.

6.3.2 Users' satisfaction in cultural experiences

The characteristics of symbolic, intrinsic, and subjective dimensions inherent in cultural experiences play a pivotal role in shaping and influencing user satisfaction.

The symbolic dimension, with its profound ability to captivate and seduce the spirit of the user, goes beyond the paradigm of the rational consumer, distancing itself from the conventional terms of exchange (Bourgeon-Renault, 2014). The presence of symbols within cultural encounters alters the classical dynamics of transactional rationality, introducing a transformative element. This symbolic value involves not only an exchange rooted in the rationality of price mechanisms and utility maximisation but also a nuanced exchange that presupposes an emotional and identity-based choice. This choice exists outside the realm of calculated costs and benefits, emphasising a deeper, more meaningful connection with the cultural narrative. As users identify with the symbolic message, it becomes a catalyst for emotional resonance and a sense of shared identity, thereby significantly influencing and enriching their overall satisfaction with the cultural experience.

The intrinsic qualities, encompassing intellectual, aesthetic, emotional and social dimensions, transform cultural engagement into a rich and fulfilling journey. This multifaceted depth becomes a cornerstone for heightened user satisfaction.

Cultural experiences, with their intrinsic qualities, provide opportunities for learning, reflection, emotional engagement, social interaction etc. Each interaction during the experience contributes to the construction of satisfaction. For instance, the perception of new information, the emotion stirred by a work of art, aesthetic contemplation, or social interaction within a cultural context are all elements that add up in shaping the user's satisfaction judgement (De Rojas & Camarero, 2008).

Moreover, the subjective dimension extends to the concept of satisfaction and fulfilment derived from cultural engagement. The subjective dimension recognizes the diverse perspectives and individualised responses that participants bring to cultural experiences. An individual's level of satisfaction is not solely determined by external factors but is deeply influenced by their internal responses, expectations, and the alignment of the experience with their personal preferences and values (Kirchberg & Tröndle, 2012; Falk & Dierking, 2013; Packer & Ballantyne, 2016). Recognizing and addressing individual subjectivity not only acknowledges the distinctiveness of each person's encounter but also ensures that cultural offerings resonate with their expectations and values. This alignment enhances satisfaction derived from immersive and transformative experiences.

6.3.3 Key factors to understand user experience in cultural engagements

Given the unique characteristics of the cultural experience and how they influence the construction of user satisfaction, considering certain elements becomes crucial when evaluating user experience. The significance of the symbolic, intrinsic, and subjective dimensions of the cultural experience emphasises the need for an audience-centred perspective (Falk, 2016) in constructing the evaluation of the experience. This means understanding the individual's needs, motivations, expectations, and past habits to assess their satisfaction.

Additionally, considering the transformative power of the cultural experience, it's essential to determine if the audience has genuinely undergone this transformation – whether they have learned something, felt emotions, or experienced a sense of wonder. In essence, understanding the perceived effects of the experience is crucial. Satisfaction becomes a dynamic interplay between expectations and perceived effects, underscoring the intricate connections that weave through the entire user experience in cultural consumption. Therefore, these elements must be taken into consideration in evaluating the user experience. We can outline the items to consider as follows:

6.3.4 Users' background and expectations

Users' background and expectations are crucial elements that must be considered in the user experience, providing insights into the user's anticipated expectations and motivations for engaging in a particular cultural experience. Understanding the user's background allows designers to gain clarity on the audience's needs and preferences, facilitating a more tailored and engaging encounter. Recognizing what drives an individual to choose a specific experience and delving into their background aids designers in anticipating how the audience might interact with the cultural content. In the realm of cultural consumption, where subjectivity plays a significant role, individuals are not entirely passive consumers but actively engage with and interpret the content they experience. This acknowledgment of the user's subjectivity enhances the ability of designers to create meaningful and resonant cultural encounters that align with the diverse backgrounds and expectations of their audience. Some variables that we can measure are therefore motivation, expectation, frequency of attendance, cultural habits and cultural interests.

6.3.5 Perceived effects in cultural experiences

Understanding users' perceived effects during cultural experiences is fundamental for a comprehensive evaluation. These elements serve as key indicators to grasp what individuals have truly encountered, assessing whether they found the experience enjoyable, gained new knowledge, or experienced emotional engagement. For instance, visiting an exhibition inspired by a historical event may lead to the discovery of previously unknown facts or a reconsideration of one's perspective on a topic. Songs could encompass the full spectrum of feelings evoked including pleasure, amusement, sadness, fear, and excitement. Watching a movie can bring back memories.

The transformative nature of the experience is scrutinised, deciphering the extent and nature of the changes users undergo. By delving into these aspects, experience designers and cultural managers can gain insights into the multifaceted impact of cultural engagements, capturing the essence of the transformation and enrichment users derive from their experiences.

6.4 A holistic approach to understanding cultural immersive experience from users' perspective

Cultural experiences shape the lens through which users perceive and engage with immersive content, influencing their emotional responses, and cognitive connections. Introducing the perspective of content and its impact on cultural experiences opens new ways for better integration of immersive technology into the realm of culture, which would lead to even more meaningful immersive encounters. In the context of culture, where depth of content is critical to foster deep engagement, this paradigm shift ensures that technological innovations are harnessed to amplify the value of the cultural experience and enrich the cultural narrative rather than ignoring it.

The prevailing emphasis on technology in UX for immersive experiences often overlooks the pivotal role that content plays in shaping the immersive encounter in the cultural domain, evidencing the need of a paradigm shift that holistically addresses immersive technologies in cultural experiences. Immersion happens as a result of focused attention, where the mind is absorbed in the ongoing activity (Agrawal *et al.*, 2020, p. 407). While it is true that technology may initially capture attention through its sophistication, it is the content that invites the user to interact and engage in a cultural activity (Manolika & Baltzis, 2020), thus requiring appropriate attention.

Moreover, the richness of immersive experiences goes beyond the attributes of the technology employed; it is intrinsically linked to the quality and meaning of the content presented in immersive environments. When users are immersed in an experience, they are able to focus on the information they find meaningful without distraction (Weibel *et al.*, 2010). The ability to withdraw from reality through mental involvement depends largely on the individual characteristics and content properties. Furthermore, individual characteristics determine what contents are meaningful for the individual, such as personality traits, interests, and personal knowledge.

In the realm of cultural immersion, the role of content extends beyond establishing a context for interaction; it assumes a central position, playing a profound and multifaceted role in the overall experience. Content has the potential to elevate the experience from a mere technological spectacle to a deeply meaningful engagement. This paradigm shift calls for a holistic understanding that integrates technology and content seamlessly. Recognizing the symbiotic relationship between the two allows for the creation of immersive experiences that are not only technologically advanced but also culturally resonant.

The UX approach to immersive technology examines how user characteristics influence the way individuals engage with interactions facilitated by technology. These characteristics, which include aspects such as knowledge, personality and tastes or interests (Kim *et al*., 2020), align with those examined in cultural visitor studies, but with different approaches. The UX approach is interested in how user characteristics influence satisfaction in using a technology. In the cultural realm, visitor studies are interested in how user characteristics influence the user perception of a cultural experience, in terms of symbolic value. For instance, consider a VR application designed for a museum exhibition, featuring personalised avatars and aesthetically pleasing interfaces aligned with the user's preferences. This approach aims to foster a more immersive and user-centric interaction. However, while the development of the VR app may be optimal from a UX perspective, it may be failing in content-related aspects (e.g. anachronisms). While these may not directly impede the functionality of the interface, they can significantly impact the individual's overall satisfaction with the immersive experience.

Adapting this approach to immersive experiences involves considering a range of variables that reflect the intricacies of cultural encounters. These are aspects already considered in the UX approach, such as the user's knowledge, personality, preferences and experience of the product, but limited to the analysis of the technology. The key lies in integrating components that consider interactions with cultural content. This approach facilitates a comprehensive exploration of the user's background, covering expectations, motivations, and interests in both technology and content — elements widely acknowledged as predictors of satisfaction. Furthermore, at the experiential level, it allows for the synergistic impact of technology interactions with the intrinsic dimension of culture, evaluating the resonance that the overall experience elicits in individuals.

Identifying users' interest in immersive experience and cultural experience based on online search behaviour.

To support our approach in evaluating the user experience, empirical research was conducted to examine user online searches related to immersive experiences. This approach aimed to capture the diverse ways on how users express their own interests and expectations regarding immersive experiences, acknowledging the multifaceted nature of user engagement and user perception with technology and cultural content. The analysis of these keyword groups provides insights into the nuanced aspects users associate with immersive experiences, informing a more comprehensive understanding of their preferences and expectations.

6.4.1 Methodology

For the empirical research, two groups of keywords were pre-selected, one more closely associated with technology and the other more closely tied to aspects derived from the cultural content experience, as shown in Table 1. The keywords assessed for user-demand in the research are composed of three-word combinations, with *immersive* being a constant term. To observe the keyword's popularity, they were used as queries (e.g. *cultural immersive technologies*, or *immersive technologies*). These keywords maintain the consistency of the term *immersive* while being accompanied on one side by a word related to the experiential aspect, such as event, installation, exhibition, etc. On the other hand, concerning culture, words have been combined with semantic variations that represent some of the intrinsic dimensions of the cultural experience, including emotional, aesthetic, etc. Regarding technology, we incorporated words related to different types of technology used in experiences, such as AR, VR and MR. This approach allows for a comprehensive exploration of the diverse semantic facets of immersive experiences, considering both the experiential and cultural dimensions, as well as the technological aspects. In the Table 1, the various keywords which have been selected can be observed. The selected keywords were monitored by employing Application Program Interfaces (API), specially programmed software which have been connected to all relevant platforms, using

Table 1. Keywords used to examine user behaviour on the Internet.

CULTURE Keywords	-	EXPERIENCE Keywords
aesthetic cultural fascinating emotional	----->	immersive experience immersive exhibition
TECHNOLOGY Keywords		immersive event
AR VR MR	----->	immersive installation immersive projection

search frequency or keyword related statistical data, offered by the providers themselves, as well as used by the users directly.

Search volume data is extracted from worldwide 14.103 search engines, social networks and other electronic platforms such as e-shops and media on the national domain level. Each of these counties and sources has its designated API and hence needs to be handled separately. The harvested data are then analysed systematically to reveal and validate the queries submitted by national Internet users and the frequencies of those inquiries in their own language.

Some additional parameters need to be specified. First, the data crawling is parameterized to take in account only the predefined geographical countries (domain extensions) where partners of the *ARTCAST 4D* project come from and where immersive pilots will be taking place such as Italy, UK, Greece, Belgium, Spain, France and Switzerland. Second, it is important to examine and compare numerous Search Engine (SEs'), Social Networks (SMs'), and E-Shops (ESs') to assure a very high level of country and online user coverage. Third, the gathered empirical data are cross-validated and tested for reliability. Therefore, patterns are identified and topics are reasonably compared across most of the popular tech intermediates and countries. The best scope for measuring valid search volume data on various digital channels is the ∑ of the arithmetic average of search scores over the previous 30 days at any given time. These 30 days show highly aggregated and anonymous user-results for each keyword of the immersive topic range on each channel. Reliability testing is done by comparing the multi-channel results of all search queries, with the entire number of active users in a given country (by top level domain). The reliability testing is based on ITU figures which identify in the year 2022 active users. The data were gathered on February 24th on a 30 day's average level, therefore also including data back to January 24th, 2024.

6.4.2 Results

The results indicate that, at a general level and aggregated across all *ARTCAST 4D* countries, users are more inclined to search for terms related to the cultural experience rather than technological terms when referring to the immersive experience, as depicted in the graphs (Figure 1, Figure 2). This trend suggests a greater emphasis or interest among users in aspects associated with the cultural content and experiential dimensions of immersive encounters, underscoring the significance of cultural engagement over purely technological aspects in the context of the *ARTCAST 4D* project.

Comparing the two user search graphs, a notable trend emerges: the keyword most searched in relation to technology has a volume of less than half of the most searched keyword associated with culture. This discrepancy underscores a significant user preference towards cultural aspects over technological aspects when it comes to seeking immersive experiences and experiencing immersive installations.
It suggests that users are more inclined to explore and engage with content that emphasises cultural richness, emotional resonance, and experiential depth rather than focusing solely on the technological features of immersive encounters. This insight reinforces the idea that, for users, the immersive experience is not solely defined by technology but is deeply intertwined with the content dimensions it offers.

In particular, among the keywords related to culture, those that demonstrate heightened interest from users include *emotional immersive installation* and queries formed by combining the words *culture*, *immersive*, *exhibition*, *installation*, and *experience* (Figure 1). The increased interest in keywords such as *emotional immersive installation* and combinations involving culture and immersive experiences suggests a nuanced user inclination. It implies that users are not solely seeking technological aspects but are actively seeking immersive encounters that evoke and connect emotional and cultural

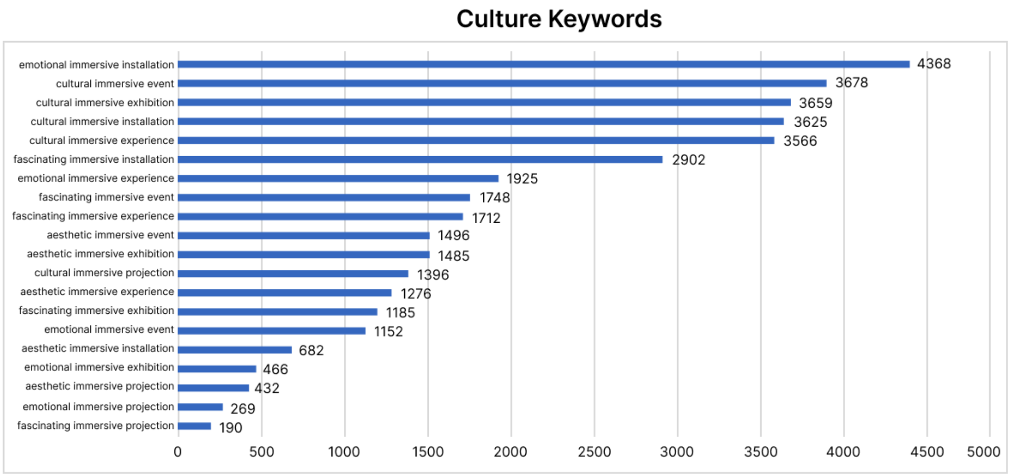

Figure 1.
Volume search of culture keywords (number of aggregated keyword searches in 9 countries).

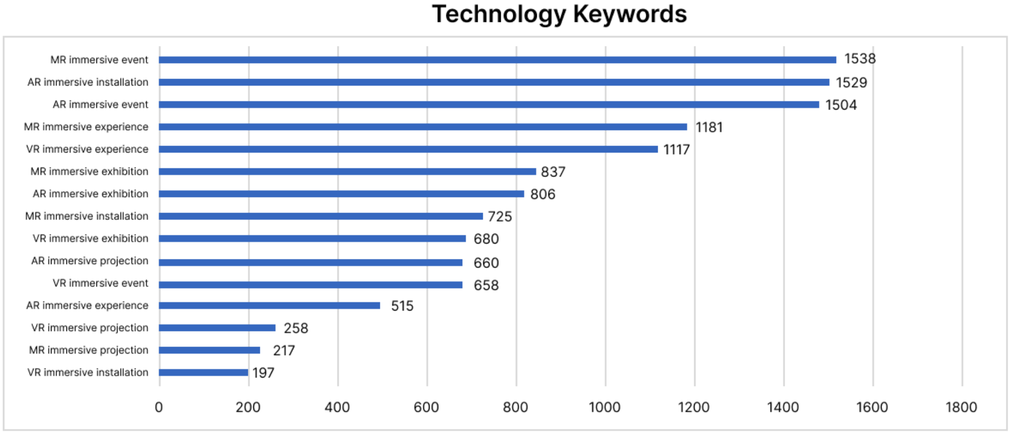

Figure 2.
Volume search of technology keywords (number of aggregated keyword searches in 9 countries).

dimensions with immersion. The emphasis on emotional immersion indicates a desire for experiences that go beyond the technological framework, focusing on eliciting profound emotional responses. Furthermore, the queries combining culture, immersive, exhibition, installation, and experience highlight the importance users place on the holistic encounter – one that seamlessly integrates technology with cultural content.

This pattern in user search behaviour aligns with the notion that the value of immersive technology in cultural contexts is deeply entwined with the emotional and cultural impact it delivers. Users seem to prioritise the emotional and experiential aspects of cultural immersion, seeking a blend of technology and content that resonates on a deeper, more meaningful level. This insight provides valuable guidance for designing and communicating immersive experiences that prioritise emotional and cultural engagement, aligning them with the preferences and expectations of the audience.

6.5 Conclusion

This chapter has explored the intricate relationship between immersive technology and cultural experiences, emphasizing the need for a holistic understanding that integrates both technological and cultural dimensions. The chapter delved into the UX design in immersive technology, highlighting a predominant bias toward technology, overlooking the critical role of content in shaping immersive encounters. The discussion emphasized the importance of an integrated approach considering both technological and content aspects, to develop more meaningful and culturally resonant immersive experiences.

Cultural experiences in the realm of immersive technology were analysed, recognizing them as transformative and multifaceted interactions. The chapter underscored the symbolic, intrinsic, and subjective dimensions inherent in cultural experiences, demonstrating their pivotal role in influencing user satisfaction.

The empirical research on user search behaviour for immersive experiences reinforces the discourse emphasis, revealing a notable trend in the online demand for immersive experiences across different channels. Users exhibited a greater inclination toward cultural aspects than technological ones, emphasizing emotional and experiential dimensions. Keywords such as *emotional immersive installation* and those combining culture, immersive, exhibition, installation, and experience indicated users' nuanced preferences for immersive encounters that resonate emotionally and culturally. By proposing a holistic UX approach, the chapter integrates user aspects such as knowledge, personality, preferences, and product experimentation. It advocates for the seamless integration of components for cultural content interactions, allowing for a thorough exploration of user backgrounds, including expectations, motivations, and interests in both technology and content realms. The approach extends to evaluating user perceptions of the overall experience, considering both cultural and technological dimensions. This user-centric methodology aims to capture the holistic impact of immersive encounters on users.

The chapter suggests that, by aligning technological advancements with cultural richness, immersive experiences can become not only technologically advanced but also culturally resonant, meeting the diverse expectations and preferences of the audience. This approach ensures a meaningful and transformative immersive encounter that transcends technological spectacle, enriching the cultural narrative and deepening user engagement.

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7. Depicting future perspectives on immersive experiences through design-driven foresight workshops

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ABSTRACT

The chapter explores possible ways in which immersive experiences for the artistic and cultural fields might evolve in the future. It attempts at identifying current gaps and possibly promising opportunities for the future of this field through participatory foresight activities, organized within the frame of the *ARTCAST 4D* European funded project, and involving multiple and diverse professionals within the European consortium, as well as artists, designers, and other experts dealing with immersive experiences. Specifically, the articulation and results from four workshops are presented. Their purpose was to infer valuable trajectories for the future of immersive technologies, experiences, interaction modalities, professional figures and competences in the artistic and cultural environments through the construction of future scenarios. Several recurrent themes emerged and are discussed to infer possible pointers for current practices. They include an emphasized level of absorption, drawing on diverse aspects of personal human experiences, from emotional to cognitive ones,

granting people's control and encouraging collective engagement. Hybrid spaces are an additional constant. Here, the integration of technology (like Mixed Reality and AI) is ubiquitous and unobtrusive and multidisciplinary teams represent a strategic advantage. These insights have the potential to serve as foundation for opening new opportunities for meaningfully advancing people's immersive experiences in artistic and cultural domains.

7.1 Introducing the relevance of design-driven foresight workshops

> ***The technoculture that we currently inhabit* [...] *was neither rationally designed nor science-fictionally predicted* (Sterling, 2009).**

These words from science fiction novelist Bruce Sterling are more relevant now than ever. As he observed fifteen years ago, we are living in a world where progress and change outpace our imagination: «We have entered an unimagined culture» (Sterling, 2009). In the context of the *ARTCAST 4D* European-funded project, which explores the potential of immersive technologies, it has been found that virtual and Augmented Reality are the most actively explored frontiers in this field at the moment. On the contrary, the latest technological advancements are not yet widely incorporated into current practices.

This rapid technological evolution makes it challenging to stay updated with new applications. Therefore, anticipating possible innovation trajectories in immersive experiences for the artistic and cultural domains is crucial for guiding efforts toward meaningful results.

As part of the *ARTCAST 4D* project's research activities, two design-driven foresight workshops were organized. These workshops blend the benefits of strategic foresight and strategic design into a unified format. Understanding the potential and motivations behind this approach is essential to appreciate the applied methods.

The constant change and uncertainty of our times make traditional forecasting methods quickly obsolete, as they rely on historical data and mathematical models (Buhring & Koskinen, 2017). Today, this limitation is evident in weather forecasting, which often fails to predict extraordinary events occurring worldwide. In contrast, science fiction and foresight, imbued with unconstrained imagination and creativity, are better suited to address uncertain situations (Sterling, 2009; Zaidi, 2019; Buehring & Bishop, 2020). These fields focus on the «imagination and creation of desirable futures scenarios» (Buhring & Koskinen, 2017), closely aligning with the design discipline's aim of improving situations while addressing ill-defined problems (Simon, 1969; Buchanan, 1992).

The relationship between science fiction, foresight, and design has been explored by various scholars (Sterling, 2009; Buehring & Bishop, 2020; Bleecker, 2022; Simeone & D'Ippolito, 2022). Their purposeful integration, also referred to as «design fiction», supports the exploration of radically innovative future possibilities. As Bleecker (2022) states, «Design fiction is about creative provocation, raising questions, innovation, and exploration». And scenarios are the most common tools used to «envision, inspire, and communicate desirable directions» (Buehring & Bishop, 2020).

Scenarios serve not only as foresight practices for speculating about possible futures but also as safe spaces for experiential learning (Buehring & Bishop, 2020; Simeone & D'Ippolito, 2022). They support decision-making by providing insights that feed strategic reflections and motivate key stakeholders to act (Bootz, 2010). Participation and co-creation, at the core of both design and foresight practices, are additional essential ingredients for fueling a systemic view and achieving results that encompass multiple perspectives (Simeone & D'Ippolito, 2022).

In our approach, we integrated these elements – desirable future scenarios, unconstrained creative thinking, and co-creation with diverse actors – to explore possible trajectories for immersive experiences in the artistic and cultural fields. This integration has therefore resulted in two design-driven foresight workshops, recognized as an effective research practice for involving multiple stakeholders in participatory activities (Ørngreen & Levinsen, 2017). The workshops aimed to create a shared understanding and vision among participants by making them co-create future scenarios of immersive experiences. Then, a subsequent analysis by the project's researchers intended to provide further insights to orient strategic decisions.

In the following, the chapter details the specific methods employed, the results obtained, and discusses the insights and opportunities that emerged from the four scenarios envisioned during the design-driven foresight workshops.

7.2 Methods

Sharing the objective to explore possible trajectories for the development and application of immersive technologies in artistic and cultural environments, two design-driven foresight workshops involved multiple potential stakeholders to investigate how technological solutions, experiences, interaction modalities, professional figures and competences might evolve in the near future. These encouraged the participants to envision scenarios of innovative and disruptive immersive experiences set in 2049, focusing on the context in which they take place, the immersive environment, the elicited experience, the enabling technology, the touchpoints, and the interaction modalities engaged by the users. The selected timeframe aims to provide participants with a temporal proximity that is not overly distant, yet sufficient to stimulate their imagination regarding potential advancements in technology within the field. Additionally, a public space setting was required for consistency with the aim of the European project in which the activity was inserted. The two workshops were conducted in slightly different ways, and the details are explained below.

After the workshops, the results were elaborated and analyzed by the research team. AI-generated images were elaborated to portray the scenarios and a thematic analysis was performed to identify significant and recurring topics both in the immersive experience and the technological compartments. A back-casting activity focused on the possible trajectories for future professions and competences followed.

7.2.1 Online workshop

To guarantee greater accessibility, the first workshop (OW) was held online (on Teams with the support of a Miro board), in English, and it was recorded and transcribed for subsequent analysis. It was facilitated by four researchers and involved eight participants with diverse nationalities, backgrounds and expertise, selected among the partners of the *ARTCAST 4D* project and their connections.

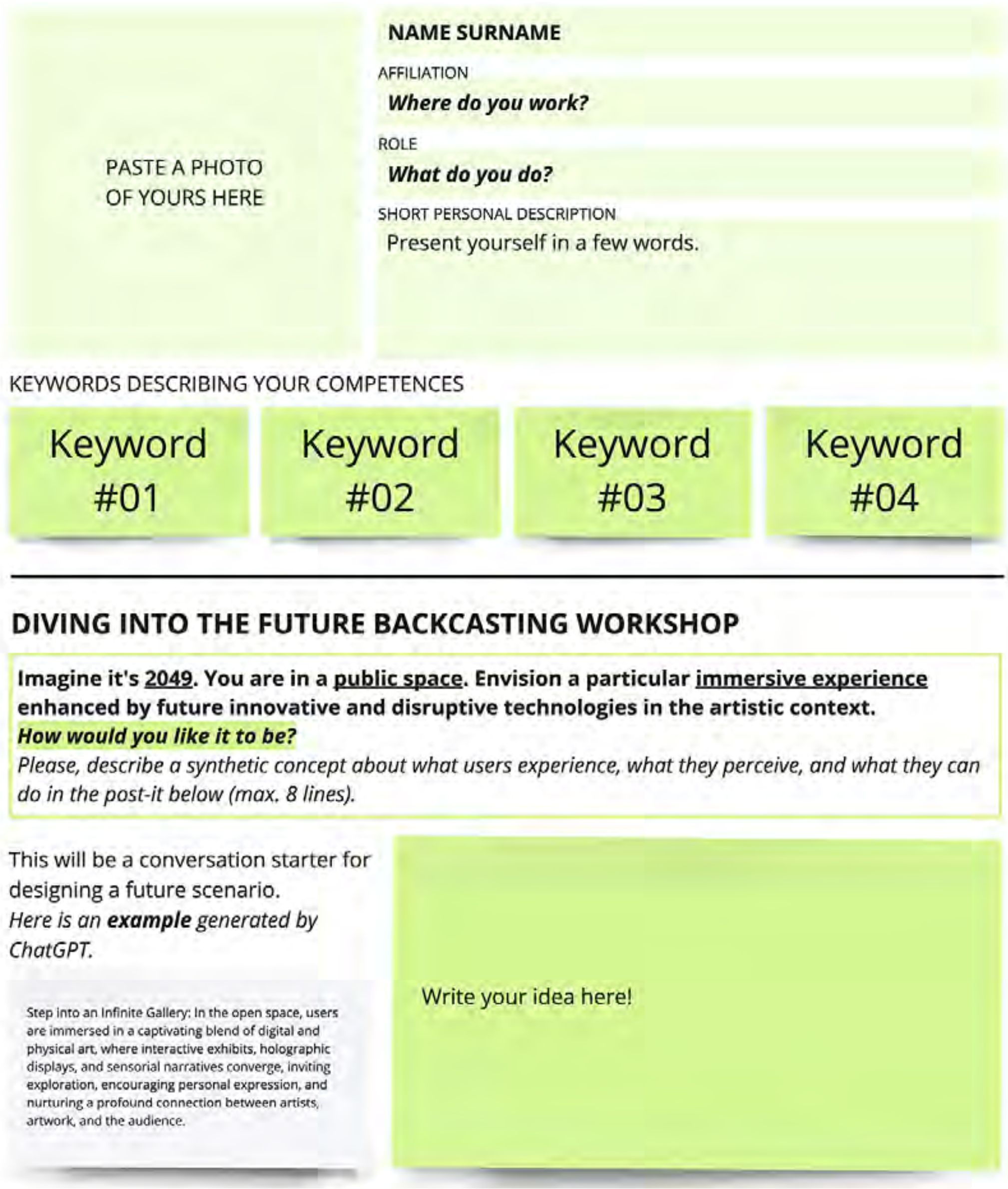
They included a media artist and an interaction designer from an interactive exhibitions studio, and six members of the consortium (two researchers in the field of cultural and creative industries, two researchers on immersive technologies in public spaces, a media publisher expert in public affairs and a project manager). An additional contribution was also given, through the provision of preliminary materials, by the CEO and Creative Director of a digital farm, who could not attend to the workshop.

Indeed, to optimize the time at disposal, all the participants were asked to fill in a digital card to introduce themselves to the others (including their names, affiliation, role, competences, and a short description) and to start envisioning possible scenarios in preparation for the workshop (Figure 1). The focus was on immersive experiences in public spaces, implementing future technologies in the artistic context.

The introductory digital cards were then used to organize the participants into two heterogeneous groups with compatible initial suggestions. Therefore, after a brief introduction of the purposes and motivations of the workshop, two virtual rooms with equal moderation teams were set up to encourage a collaborative experience. The first phase of the session aimed at identifying a shared scenario based on the preliminary propositions. Then, the idea was refined and articulated according to the points of interest previously presented and outlined on the supporting Miro board (Figure 2).

Finally, the participants were guided toward the identification of a *dream-team* of essential professionals for designing and materializing the foreseen experience (Figure 3). This activity was meant to infer possible competences and figures that might be necessary in the future.

During the workshop session, participants were encouraged to leverage their imagination and conceptualize novel technologies, tools, interaction modalities and professionals involved in the future scenario, especially if those do not currently exist. To stimulate their creativity, the research team provided boxes labelled *Suggestions from our present*, containing examples of contemporary state-of-the-art immersive technologies, tools, and interaction modalities to


PASTE A PHOTO OF YOURS HERE

NAME SURNAME

AFFILIATION

Where do you work?

ROLE

What do you do?

SHORT PERSONAL DESCRIPTION

Present yourself in a few words.

KEYWORDS DESCRIBING YOUR COMPETENCES

Keyword #01

Keyword #02

Keyword #03

Keyword #04

DIVING INTO THE FUTURE BACKCASTING WORKSHOP

Imagine it's 2049. You are in a public space. Envision a particular immersive experience enhanced by future innovative and disruptive technologies in the artistic context.

How would you like it to be?

Please, describe a synthetic concept about what users experience, what they perceive, and what they can do in the post-it below (max. 8 lines).

This will be a conversation starter for designing a future scenario.

*Here is an **example** generated by ChatGPT.*

Step into an Infinite Gallery: In the open space, users are immersed in a captivating blend of digital and physical art, where interactive exhibits, holographic displays, and sensorial narratives converge, inviting exploration, encouraging personal expression, and nurturing a profound connection between artists, artwork, and the audience.

Write your idea here!

Figure 1.
Blank introductory card for the participants to complete before the workshop to facilitate self-presentations and to start with preliminary work.

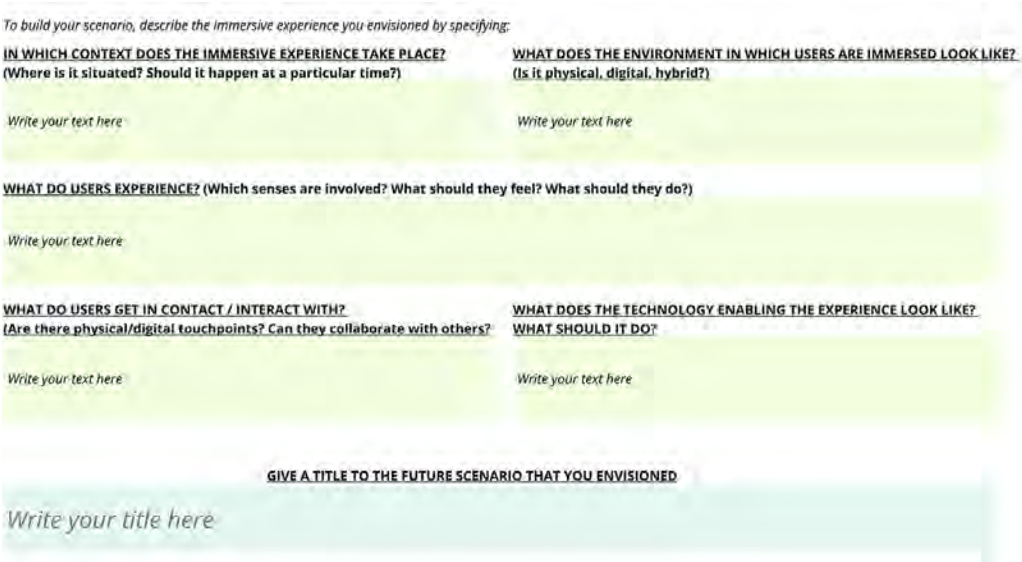


Figure 2.
Scenario construction facilitated by specific questions to define the details of the envisioned immersive experience.

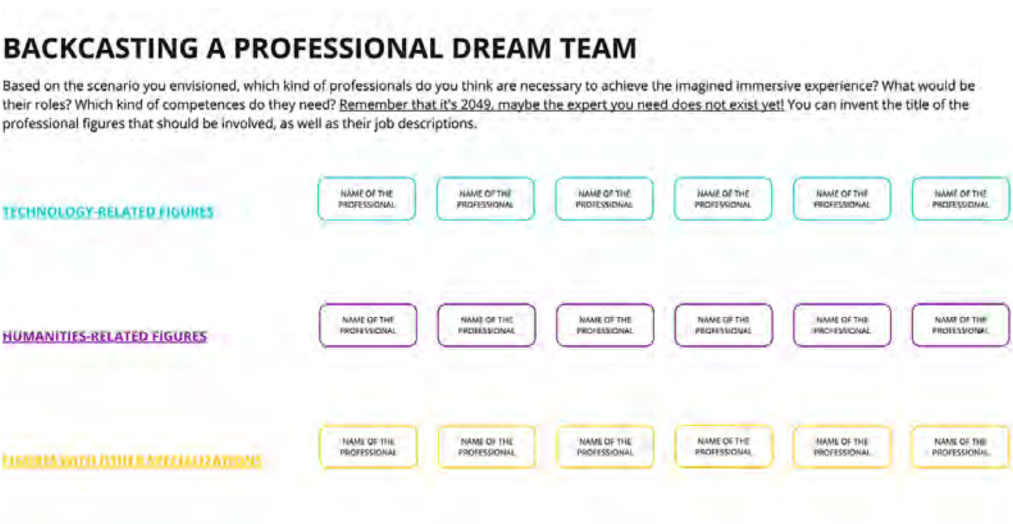


Figure 3.
Final workshop activity on the Miro board, dedicated to the creation of a professional dream team to support the envisioned future scenario.

support the scenario construction. An additional box offering suggestions about the generic skills of professionals typically involved in the design for immersive experiences and installations was also provided.

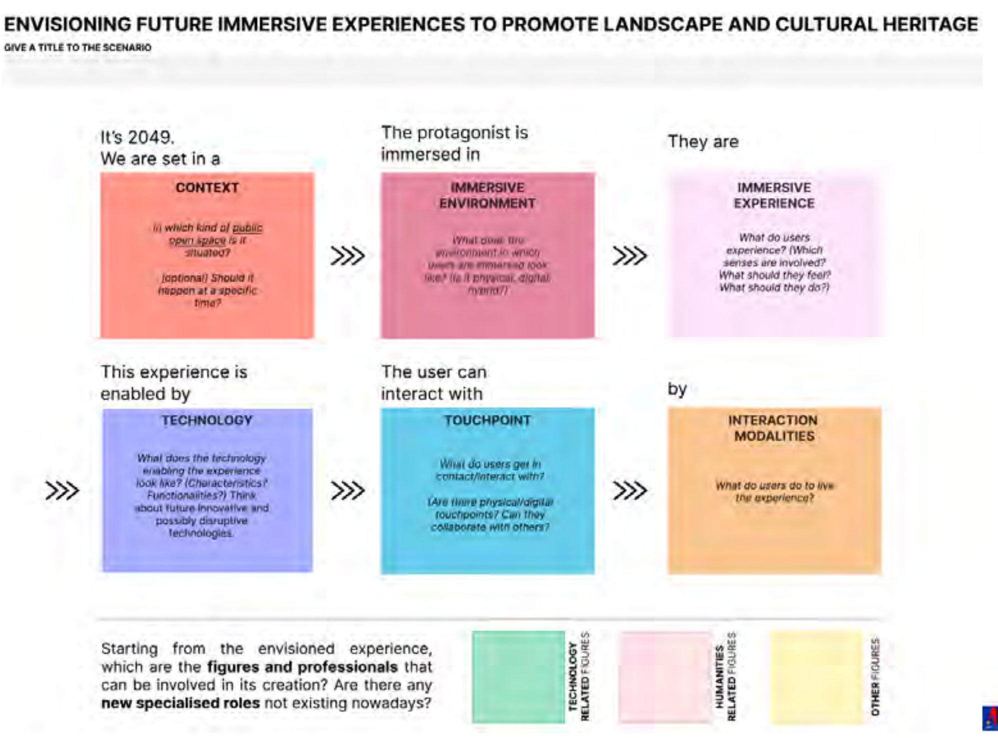
In conclusion, the two groups were brought back together to present and mutually discuss the envisioned scenarios.

7.2.2 In-person workshop

The second workshop (PW) took place in person during the Rethinking Clusters conference in Valencia. A slot of 1 hour and 30 minutes was reserved to the collaborative activity, facilitated by three researchers. Also in this case, English was employed to accommodate an international audience. It involved 11 participants, expert in different fields, namely humanities (4), research (4), technology (3), management (2), communication (1), education (1), impact (1), and media (1). Some of them selected more than one area of expertise.

As the participants registered directly on the day of the conference, no preparatory activity could be anticipated, therefore the format differed from the previous workshop. At the beginning all the

Figure 4. Support poster for the in-presence workshop. It depicts the different points to tackle to facilitate the construction of the future scenario.



attendees were asked to fill in a card to identify themselves (name, affiliation, role) and the field to which they felt they belonged the most. Based on the provided information, they were divided into two groups (of 5 and 6 people), and they were required to collectively envision future immersive experiences to promote landscape and cultural heritage (more familiar to the conference audience and still consistent with the project's scope). The format was simplified and the groups, guided by a moderator, constructed the scenario step by step, starting from the context and getting to interaction modalities, as portrayed in Figure 4. All the participants could contribute their ideas with personal cards for each point of the scenario narrative. Multiple options were displayed for discussion and finally synthesized and agreed on, collectively building the scenario on a shared poster.

Analogously to the previous workshop, the second phase consisted in brainstorming the professional figures necessary to realize the envisioned immersive experience.

Finally, the scenarios emerged in the parallel sessions were presented to the other group and together the participants tried to synthesize their distinguishing features in a title.

7.3 Results: four distinctive scenarios

Four distinctive scenarios emerged, characterized by unique peculiarities and notable connections. They are reported synthesizing both the content in the boards and posters and the discussions within the respective groups. Each scenario is presented with an overview introduction and further detailed in three sections focusing on the objects of the investigation: user experience and interaction modalities, enabling technology and tools, and the evolution of professional figures.

7.3.1 Scenario 1 (S1): *À la cARTe*. Day-by-day seamless and unconstrained art immersion

The *À la cARTe* scenario (Figure 5) unfolds in open, accessible public spaces large enough to facilitate users' interaction, like a subway train. This envisioned scenario revolves around the use of ultra-thin devices, such as contact lenses, enabling users to

Figure 5. Midjourney-generated images to represent S1: *À la cARTe*.

engage in immersive hybrid experiences facilitated by brain interfaces and body implants. These experiences seamlessly integrate into users' daily lives, allowing for control and disengagement at any moment. Users can also share their experiences with others or explore the experiences of fellow users.

User experience and interaction modalities

In this envisioned scenario, the user's immersive environment is hybrid, blurring the boundaries between the virtual and tangible worlds. Users can control the immersiveness provided by the artificial content through an Augmented Reality interface, operated via brain implants. This interface serves as a shared platform for users present in the tangible space, facilitating interaction. However, access to individual experiences requires permission before sharing. Users have the freedom to access different experiences or voluntarily disengage from the ongoing one. The system engages all physical senses, incorporating elements like monitoring heart rate, brain activity, and emotional engagement to enhance overall immersion.

Enabling technology and tools

The scenario introduces thin and lightweight wearable devices seamlessly integrated into users' everyday routines and bodies. Indeed, brain and body implants are considered as part of these wearable systems. With these devices users are immersed in high-definition, smooth, and seamless artistic experiences, due to the invisible presence of technological supports.

Evolution of professional figures

Professional roles envisioned during the workshop (Table 1) manifest a balance between technology-related, humanities-related, and hybrid ones. The participants imagined novel figures, particularly related to the expertise of sensory experiences, introducing roles like sound designers, smell designers, touch designers, and their corresponding developers — collectively referred to as *ambient designers*. These hybrid roles bridge various sensory modalities. From a technical perspective, the identified roles include developers working on design outputs, a *senses expert* with a deep understanding of sensory perception, an AI developer introducing adaptive ways to guide user flow, and specialists in brain implant technology.

Understanding human behavior and psychology is emphasized, requiring the collaboration of sociologists, psychologists, and neuroscientists with artists and creators to conceive and materialize meaningful experiences. An immersive consultant and an ethics expert (Stückelberger & Duggal, 2018) ensure ethical considerations

Table 1. List of professional figures depicted by the participants for S1.

Technology-related	Humanities-related	Other specializations
AI/software developer	artists	UX/UI designer
electrical engineer	creators	graphic designer
data scientist	content creator	3D designer
senses expert implant expert	content providers communication expert	smell designer sound designer
brain engineer	sociologist/psychologist	touch designer
brain interface specialist	science / humanities expert	ambient designer
smell developer	researcher	Immersive consultant
AI agent guiding the user		marketing/ communication
		project manager
		ethic experts
		architect
		neuroscientist

and user well-being are integral to the design process. Traditional roles continue to be relevant, with project managers overseeing and coordinating the process; UX/UI designers, 3D designers, graphic and communication designers contributing their expertise; communication experts supporting effective strategies; and content creators and providers shaping the artistic elements and significance of the experience. Developers and technical engineering roles, including electrical engineers, form the development and implementation team, while a data scientist analyzes various data generated by the experience, providing valuable insights to enhance the immersive experience.

7.3.2 Scenario 2 (S2): *Human shared reality in a connected world, with a deviceless experience*

This scenario (Figure 6) unfolds within museums or morphological spaces designed to facilitate interactions with physically present visitors and individuals who can only connect remotely. This hybrid environment integrates images, holograms, and avatars, linking people, contents, and places across various museums, leveraging their digital archives.

User experience and interaction modalities

In the envisioned scenario, users enjoy the virtual or hybrid space in which they are immersed, navigating it and interacting with avatars and holographic projections of objects or other environmental elements in a natural way. Collaborative experiences and interactions

Figure 6. Midjourney-generated images to represent S2: *Human shared reality in a connected world, with a deviceless experience*.

with other users and the environment are encouraged, enhancing engagement within the advanced hologram system. Visitors can initiate discussions and ask questions when approaching holographic avatars, which function as expert guides on specific topics. These avatars, controlled by AI systems, respond realistically to users' emotions and questions, serving as human-like digital touchpoints within the immersive experience.

Enabling technology and tools

The realistic immersive experience relies on AI to control holograms and other contextual variables of the museum exhibition or building itself. This includes transformative architectural technologies capable of altering material properties, such as transitioning iron from a solid to a fluid state. Aiming to convey a rich and natural multisensory experience, a molecular technology, such as OLED floating transparent screens, enhances the visual experience. Similarly, localized sound sources or *sound bubbles* contribute to immersive audio experiences. Notably, the envisioned scenario promotes a deviceless experience, eliminating the need for digital interfaces or control devices to interact with immersive elements.

Evolution of professional figures

Throughout the workshop session, participants highlighted the significant role of the AI system to guarantee an immersive experience. Therefore, the ideal team for the experience design process (Table 2) includes an AI developer, responsible for creating and implementing algorithms that fuel interactive elements so that people perceive them to be behaving in a natural way. The AI expert optimizes the system for seamless integration with the immersive environment.

As an evolving entity, it continuously learns and adapts to users' interactions, preferences and emotional cues, offering personalized responses and recommendations for significant enhanced experiences. The creative team does not present major revolutions. Key roles comprehend the artist conceptualizing the immersive experience; the curator selecting and arranging digital artefacts to create a cohesive engaging and educating narrative; and the artistic director providing guidance and oversight to ensure the alignment and achievement of artistic and curatorial objectives. The importance of the collaboration with anthropologists and archaeological experts is emphasized to ensure accurate representation of cultural heritage and provide unique perspectives. Furthermore, a scientific committee should supervise the scientific accuracy of the information provided.

To complement the reflections emerged in the limited time at disposal, additional roles were identified by the research team, based on the most obvious competences needed for the materialization of the immersive experience as discussed throughout the scenario generation. These include a hologram developer managing the generation of avatars and other interactive digital elements; 3D artists, designers, and animators creating realistic and captivating holographic representations; and a 3D scanning expert for deriving content from real-world artefacts.

Technology-related	Humanities-related	Other specializations
AI developer	artists	Scientific committee
AI programming itself	curator	
AI expert	artistic director	
Shared digital archivists	archeological team	
	anthropologist	

Table 2.
List of professional figures depicted by the participants for S2.

7.3.3 Scenario 3 (S3): *Afterverse. Rebooth culture through death*

In this dystopic scenario (Figure 7), the immersive experience takes place a decade after a disruptive event reshaped civilization. People (possibly the last ones on Earth or otherwise) find themselves enclosed by a forever life-preserving dome within a cemetery space. Temporal boundaries have dissolved, and the living environment is a hybrid metaverse where distinctions between digital and physical reality are intentionally blurred. Within this unique setting, the cemetery serves as a backdrop for individuals to experience and understand the profound concept of death (of people, civilization, and time), which is the ultimate invaluable heritage to preserve. Activities unfold within the dome during the day, transitioning to cinema events at night. However, the core immersive experience lies within the indirect interaction with each other's memory, which allows to build and learn multifaceted meanings associated with time and death.

Figure 7. Midjourney-generated images to represent S3: *Afterverse. Rebooth culture through death*.

User experience and interaction modalities

Users in this hybrid metaverse have the liberty to navigate and engage with the space, with the major purpose to explore and preserve what being human means. This is possible and culminates in the interaction with others. People's frequencies of memory resonate with each other's when they gather, fostering a collective narrative that reconstructs the concepts of time and death. The experience enables a unique form of social interaction where individuals, simply by being present, can consciously or unconsciously share and interact with each other's memories. Living, moving, seeing, touching, and feeling with others become integral aspects of the immersive encounter, which radically synthesizes and amplifies the spreading of the most fundamental cultural heritage: understanding the value of time and death in giving life a meaning.

Enabling technology and tools

At the core of this immersive experience is the life-preserving dome, a bubble space hosting a software spread through the air. This enables the interaction and sharing of memories among its inhabitants. The dome not only physically encloses the space but also serves as a technological conduit for the dissemination of the software, enabling seamless interaction. The technology allows users to engage with the memories of others, contributing to the collective narrative that shapes their understanding of what being human means.

These technological elements provide a unique platform for users to explore the concept of death in a dynamic and interconnected manner, which preserves and promotes the spreading of the most fundamental cultural heritage.

Evolution of professional figures

The future professional landscape for this scenario includes roles that span a diverse spectrum of expertise (Table 3). Noteworthy figures include a cybersecurity expert specializing in the protection of memories, an AI creative driving the artistic elements of the metaverse, and an ethologist to understand the behaviors within the hybrid space.

Technology-related	Humanities-related	Other specializations
Engineers	Art scientists	Game designers
Software developers	Linguists	neuroscientists
AI specialists	archeologists	architects
AI psychiatrist	philosophers	ethologists
Hackers	psychologists	biologists
Cyber security manager	AI creatives	criminal
		priests
		rabbis
		handyman

**Table 3.
List of professional figures depicted by the participants for S3.**

An AI psychiatrist, trained by an ethologist, takes on the responsibility of curating and feeding the global memory. Professionals like rabbis, priests, archaeologists, linguists, and game designers play vital roles in guiding and engaging participants. Additionally, a range of scientific experts, including neuroscientists, biologists, and psychologists contribute their knowledge to enrich the immersive experience. The pervasive nature of the experience calls for architects, engineer, and handymen to design and maintain the life-preserving dome, ensuring its seamless integration with the digital elements. Philosophers contribute to the conceptual depth, while hackers and criminals pose challenges that may need addressing. Basically, the scenario establishes a diverse professional landscape, uniting various fields to create a meaningful and thought-provoking immersive experience.

7.3.4 Scenario 4 (S4): *Multisensory discovery. Bubbles for educational tourism*

The envisioned experience (Figure 8) has educational purposes and particularly targets children but can be extended to a wider tourism. It is set in an open-space archaeological or historical site, such as ancient Roman or contemporary ruins. Digital components seamlessly merge with the physical reality within a hybrid natural environment, fostering a rich learning experience for children. The aim is to provide an interactive and enjoyable exploration of historical places, integrating memory and future in the present. Children engage in a dynamic learning process, sharing the educational and emotional experience with others. They not only witness historical sites in their original context but also actively participate in creating narratives in collaboration with others, enriching their understanding of the past.

Figure 8. Midjourney-generated images to represent S4: *Multisensory discovery. Bubbles for educational tourism*.

User experience and interaction modalities

In this hybrid natural environment, children have the opportunity to see themselves in historical reconstructions, offering a glimpse into the past, such as the age of the Roman Empire. The addition of a digital dimension overlays elements like clothing, food, accessories, etc., enhancing the historical context. The environment is designed to stimulate all senses and support various forms of interaction with tangible and intangible touchpoints, including touch, voice commands, and movement. For instance, children can activate holographic bubbles that encourage an immersive learning experience by providing guidance, information about the place, and connection with remote sites. Collaborative story creation is also encouraged, allowing children to unleash their imagination and share narratives with others, combining perspectives and inputs, and bringing a new life into the place where they are.

Enabling technology and tools

The environment is augmented by projections in the air and 5D sound, complementing the physical reality of the archaeological site. The environmental responses to users' actions are made possible by autonomous technology and highly accurate tracking systems (e.g., body and eye tracking). Holographic bubbles, serving as educational guides, follow and can be activated by children through touch, voice, or movement to enrich their exploration of the historical site.

Evolution of professional figures

Also in this case, the development and execution of the immersive educational experience require a diverse set of professionals (Table 4). Software and AI developers play pivotal roles in creating and optimizing the digital components, ensuring a seamless and engaging user experience. Various engineering disciplines (including mechanical, electronic, and civil), as well as technicians responsible for IT facilities are essential for the integration and maintenance of the technological infrastructure.

Historians, archaeologists, cultural guides, and educators in collaboration with digital multimedia artists and content creators shape the educational content and contribute to the narrative development and other creative aspects of the immersive experience. Their work should be complemented by sustainability consultants, impact assessment specialists, behavioral scientists, and disabilities experts to ensure the responsible design of the immersive experience, catering to diverse needs and perspectives within society.

Psychomotricists and physicians can also contribute to the understanding of the psychological and physiological impact on children.

Finally, decision makers in public administrators, such as a Chief Immersion Officer at the city council, can oversee the integration of such experiences into cities agendas, and communication specialists should provide effective public engagement and communication strategies.

Table 4. List of professional figures depicted by the participants for S4.

Technology-related	Humanities-related	Other specializations
technicians responsible for it maintenance	digital multimedia artists	sustainability consultant
ai developer	psychologists	communication specialists
software developers	historians	educators / teachers
engineers (mechanical, electrical, civil…)	sociologists	psychomotricists
a virtual figure created for immersive works	researchers	physicians
	art historians	content creators (social media)
	archeologists	public administrations
	behavioral scientists	chief immersion officer at city council
	art-scientists	architects
	cultural guides	neuroscientists
		disabilities experts
		designers

7.3.5 Discussing recurrent patterns and possible trajectories for future immersive experiences

The outcomes derived from the workshops offer distinctive insights for future immersive experiences, portraying quite different scenarios. Yet, an evident tendency emerges towards achieving deeply seamless immersion within hybrid realities, where digital augmentations enrich the physical environment. The holistic involvement of individuals to foster immersive experiences reverberates across all aspects examined in the study, which are discussed in the following, highlighting the most recurrent themes.

User experience and interaction modalities

Aiming for a fully immersive experience, multi-sensorial stimulation, also aimed at triggering emotional responses, has been a topic of discussion in all the groups and emerged in most of the scenarios.

Indeed, the envisioned environments are absorbing and captivating to transport people to alternate realities or heightened states of engagement. Reflecting the attention that studies on immersive experiences are paying to the involvement of all human senses (Sommer *et al.*, 2020; Zhang, 2020), S4 particularly cares for the sensory aspects of the experience to blur the boundaries between physical and Virtual Reality. S1 even makes sensory and emotional engagement an active and integral part of the experience, including monitoring implants that enable a responsive adaptation of the system.

Additionally, all participants made an effort to ensure natural and effortless interaction modalities to reinforce the seamless integration of digital elements into the physical environment. S1 and S3 enable brain inputs, while S2 and S4 invest on digital elements that people can interact with as if they were real (avatars behaving like real people in the first case, and high-fidelity spatial reconstructions in the second).

Nonetheless, keeping people in control of the experience is a well-regarded concern, explicitly addressed in all the scenarios. Indeed, users are provided with the agency to connect or disconnect from the immersive experience, choose the level of immersiveness they prefer, or whether to interact with other people.

Connection is another recurrent topic. Often, the possibility for a digitally enhanced immersive experience has been interpreted as an opportunity to connect people with places that are distant in space or time (S2, S4), with artifacts that would not be accessible or that can be enjoyed from a distance without polluting for transportation (S2) or with other individuals sharing the same space (S1, S3). The latter is further reinforced by the need for active collaboration emerged in S2, S3, and S4 to increase the sense of immersion, respectively shaping the experience, pursuing a common goal, and creating a shared narrative.

In this endeavor, the pursuit of a truly human-centered approach to the design for immersive experiences seems a promising trajectory. The envisioned scenarios suggest the importance of triggering the deepest levels of human beings and uncovering their deepest needs, including agency and sociality. Immersive experiences should then go beyond being entertaining and people's more profound expectations are yet to be investigated.

Technological trajectories

The prominent commonality among all the experiences is the tendency toward seamless integration of digital and physical realities. Immersion is granted by a fluid and interconnected experiential landscape with blurred boundaries between digital and physical realms. In line with Weiser's vision of invisible interface and ubiquitous computing (1993, 1994), the barrier between users and the virtual dimension is intentionally undistinguishable. The envisioned technologies are minimalistic and unobtrusive, with extremely thin embodied devices (S1, S3), or imperceptibly spread (S3), integrated (S2), and superimposed (S4) on tangible reality.

All the scenarios portray an almost deviceless experience, which can be mainly attributed to the continual miniaturization of components and the technological advancements leading to lifelike digital assets, behaviors, and interactions. Both factors contribute to the perceptible augmentation of one's surroundings to fully immerse people in the sensory and cognitive aspects of the experience.

To materialize these hybrid realities, holograms and projections are recurrent in the envisioned examples. Operating directly in the physical environment, these offer an additional layer to reality with which people can interact to discover contents (S2), be guided and experience places in a different way (S4).

Harnessing sensory sensations more holistically is another key element of the foreseen scenarios. On the one hand, participants were concerned about stimulating multiple senses, for instance adding quality environmental audio in addition to the realistic visual stimuli (sound bubbles in S2 and 5D sound in S4). On the other, they wanted to capture people's perceptions and physiological responses to guarantee more natural and personalized interactions. For this purpose, brain implants (S1, S3), and advanced tracking systems (S4) were proposed, encompassing bodily sensations, emotions, and memories. Additionally, in all the examples, AI systems are recognized a pivotal role in enabling seamless interactions. Similarly to how large language models are currently promoting natural conversations with machines, AI systems are introduced to guide people's experience and control the behavior of digital elements, making them more truthful, optimized, and adaptive to the context and users' needs.

Therefore, echoing what emerged from the reflections about user experience and interaction modalities, technology should evolve and be applied in ways that empower people, as an invisible enhancer of their experiences. While the mentioned technologies seem to be naturally headed toward this goal, further attention to identify meaningful applications for the artistic and cultural fields might benefit the outcome, possibly unveiling innovative possibilities that effectively respond to people's expectations.

Evolution of professional figures

Although some groups dared more than others in imagining how the professional field would adapt to the requirements of the new experiences, no major changes can be observed in the general structure of the necessary figures. Indeed, some roles, revolving around three domains, are expected to endure over time.

Unsurprisingly, digital technologies experts enabling the experiences are integral part to all the scenarios, and AI developers are a constant in addition to case-specific technicians.

As well, counterparts in the humanities are also deemed essential. Indeed, a tendency toward human-related professions is not only evident, but is also addressed from different perspectives, ranging from psychology (S1, S3, S4) to sociology (S1), behavioral science (S4), anthropology (S2), neuroscience (S1, S3), to include even priests and rabbis (S3).

Finally, decision-making and organizational figures are indispensable to coordinate projects engaging a diverse set of professionals. Their identification varied among the scenarios, including project managers and artistic directors (S1), curators (S2), and even public administrators (S4) to concert the cultural initiatives with their cities' agendas.

Overall, a holistic look toward the professional domain revolving around immersive experiences can be observed. Already in the sensory area, the envisioned experiences go beyond the common visual ones, ranging from the sense of smell to bold memory transmissions, for which new specific experts will be needed. Still, all the participants seemed well aware of the broader set of professionals needed to accomplish truly immersive experiences. In fact, to properly take care of every detail, multiple competences were identified and would be needed. This leads to the recognition of multidisciplinarity as the most significant requirement identified by all the groups. Their reflections naturally turned to diverse professionals involved in the design and materialization of future immersive experiences, to encompass a wide array of knowledge domains, including arts, engineering, sciences, humanities, and design. For instance, to enable the brain-based experience of S1, the list of professionals includes medical and technical experts (neuroscientists, brain engineers, implant experts), people curating the contents (creators, artists, content providers) and materializing the experience itself (brain interface specialists, AI and software developers, etc.). This propensity for multidisciplinarity is not only consistent with the multiple dimensions involved in immersive experiences (on a cognitive, emotional, interactive, and technical level), it also reflects a very timely discourse emphasized in different fields, from design to ethics and AI, and clearly synthesized by von Schomberg (2013) in the Responsible Research Innovation field. He sustains that an inclusive process is essential for societally-desirable innovations where «technical innovators become responsive to societal needs and societal actors become co-responsible for the innovation process», and this cooperation and co-responsibility can be pragmatically inferred from the *dream teams* envisioned by the participants.

In the end, from the professional perspective, no radical changes would be necessary at the moment. However, strengthening the involvement and collaboration between different professionals could be the key to unlocking new opportunities and supporting the development of more meaningful experiences and technologies. Indeed, while practitioners from different fields might already be working in parallel on some projects, engaging them in participatory design and development activities might prove very valuable to share understanding and knowledge, fueling more beneficial outcomes for all the people involved (Avram *et al.*, 2019).

7.4 Conclusions

The exploration of future immersive experiences, conducted in the online and in-presence workshops, across four different scenarios revealed a convergence toward deeply natural and multi-sensory immersion within hybrid realities, characterized by effortless interaction modalities. The importance of users maintaining control while connecting with distant places, artifacts, and people, and fostering collaborative and shared experiences is emphasized. The envisioned integration of digital and physical realities is seamless, utilizing ubiquitous, unobtrusive technologies like holograms, projections, AI, and advanced sensory tech to ensure responsive interactions. Professionally, these scenarios highlight the importance of multidisciplinary teams, blending traditional roles with human-related professions, to holistically address the complex, systemic nature of immersive experiences while maintaining the essential role of technical and domain experts.

Overall, it seems that the ongoing development of AI systems, the advancements in sensory technology, and the integration of interdisciplinary expertise markedly shaped the scenarios, underlining the evolving nature of immersive experiences. Indeed, these developments and the inferred insights can pave the way for transformative and enriched user experiences, bridging the gap between technology, artistic and cultural expressions, and people.

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Immersive technologies are transforming how we experience art, history, and culture, offering unprecedented engagement opportunities. However, their specialised development keeps them largely inaccessible to the public, as they remain confined to laboratories. This presents a challenge for cultural institutions, which struggle to meet the rising expectations for interactive, engaging experiences in today's digital age. To address this challenge, the *Artcast4D* project is developing an accessible open-source software based on AAASeed 2D/3D platform.
It creates immersive public environments with interactive projections and crowd sensing, promoting culture as a shared, emotionally engaging experience across different countries and cultures.
This initiative focuses on efficient, cost-effective immersive solutions for cultural creativity. The *Artcast4D* project is testing its potential through four pilots in Issy-les-Moulineaux (France), Hounslow (UK), Valencia (Spain), and Athens (Greece), featuring diverse immersive experiences. By uniting creative actors, industry, cities, and civil society, it aims to boost Cultural and Creative Industries (CCIs) as drivers of innovation and competitiveness. The project is also helping develop policy guidelines for fostering Europe's immersive and accessible cultural experiences.

Designing Immersion in Art and Culture explores how immersive technologies are transforming artistic and cultural experiences, blending the physical and artificial worlds to create engaging environments. The book comprehensively reviews the current literature on immersion, unpacking key theoretical concepts and ideas. It moves beyond theory to explore public installations, demonstrating how technology is transforming everyday spaces into immersive experiences. A historical perspective follows, tracing the journey of immersive technologies from their early pioneers to contemporary applications. Throughout, diverse case studies illustrate the global impact of these technologies in art and culture, while interviews with experts provide a behind-the-scenes look at the creative processes that drive these innovations.

The book also dives into the evolving relationship between users and immersive technologies, offering a deeper understanding of their interaction. In its final section, the book envisions future scenarios where technology becomes seamlessly embedded in both daily life and artistic expression, while reflecting on the roles and expertise needed to achieve these exciting advancements.

This book may appeal to anyone interested in the intersection of technology, art, and culture, offering a glimpse into how immersive experiences could be designed and could shape the future of creative expression.

FrancoAngeli
La passione per le conoscenze