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EXECUTIVE SUMMARY

D1.3 Interdisciplinary analysis of the immersive technologies and cross-sector applications

The following deliverable presents the findings of Task 1.2 of the Artcast 4D research project, focusing on the understanding and analysis of the concept of immersion, immersive technologies, and their multifaceted applications, across various sectors, to enhance immersive experiences. The investigation comprises four main parts that go into increasing detail about current immersive technological solutions and possible future directions. Each of them addresses a specific research question.

The study revolves around four Research Questions (RQs). RQ1 *(How does the scientific literature define the concept of immersion enhanced by digital technologies?)* concentrates on the concept of immersion and immersive technologies. A literature review led to the elaboration of a definition of the concept of immersion, which comprehends insights from different perspectives. This synthesis also served as the basis for delineating five *Keys for Immersion*, depicting the most recurrent elements in the referenced literature. These have been identified as *presence, engagement, sensory involvement, embodiment, and isolation*. Furthermore, the study elucidates the most relevant immersive technologies in the current panorama.

To complement this initial research and to foster a comprehensive overview on the subject matter, some pivotal milestones in the history of immersive technologies were also identified and portrayed in a twofold way, outlining their development within their application fields and according to different categories of technologies. The reported definitions and historical key steps aimed at giving a more comprehensive understanding on the topic of immersion and immersive technologies as foundation for the project under development.

The theoretical approach adopted to explore the topic of immersion and immersive technologies required to be completed with a more practical investigation, addressing how immersive technologies are currently applied to convey immersive experiences (RQ2) *How are immersive experiences currently conveyed?*). In order to acquire this information, a total of 57 case studies referring to immersive experiences and installations were collected through an online questionnaire submitted to the members of the Artcast 4D consortium of, leveraging their expertise. The questionnaire aimed at thoroughly investigating various aspects related to the selected case studies, such as the immersive technology and tools adopted, stakeholders and actors involved, interaction modalities, experience/installation features and characteristics. The data collected have been analysed and classified to map the sample and to depict aspects of interest. Additionally, they were evaluated by the research team using the *Keys of Immersion* as assessment criteria. This intercoder agreement activity allowed the identification of their perceived immersiveness. In spite of the limits of the research, the analysis produced a snapshot of the different

possibilities available and confirmed valuable gaps and trends, mainly concerning the technologies and tools used in current experiences and installations and their features. The importance of an active involvement of the users (both giving them agency and/or engaging them emotionally) also emerged. However, a lack of precise information has been reported, mostly in relation to the design processes and the actors involved within these processes.

Following this exploratory analysis, semi-structured interviews were conducted to address RQ3: *How are immersive experiences currently developed?* This qualitative investigation was meant to deepen some relevant aspects for the development of an immersive experience that are not publicly available. The main topic of the inquiry was the delineation of the design process to realise a technology-based immersive solution, specifically detailing the actors involved, the tools employed, and the value and pain points encountered throughout the journey. Then, representatives of the teams involved in the design of some of the case studies previously analyzed were interviewed to gather these insights of the inner dynamics to develop and deliver immersive experiences. Specifically, the projects that performed the best in the research team's evaluation of the overall immersiveness (performed in response of RQ2) were selected as significant examples for this follow-up study. Although no generalizations could be inferred by such a qualitative work on five case studies, this ultimately provided the research project with an increased awareness about the inevitability of an iterative process that should engage different actors and multiple disciplinary competences within the design team for a successful outcome.

Finally, the last research activity addressed *RQ4: How might immersive experiences evolve in the future in the artistic and cultural fields?* This question was investigated by conducting an online Future Backasting workshop with the aim of conceiving future trajectories for the application of immersive technologies in the artistic and cultural field. Two groups, including consortium experts and creatives were asked to envision future artistic immersive experiences or installations in 2049. The two scenarios resulted in users engaged in immersive experiences with a noticeable reduction of perceived presence of the technology, also encompassing deviceless solutions. A possible seamless integration of technology with the surrounding environments was figured, with decreased boundaries between physical and virtual worlds. Nonetheless, few technological advancements have been depicted in relation to artificial intelligence and sensory technology.

In addition, a dream team of professionals presenting accurate skills to accomplish each future scenario, was foreseen during the workshop activity. A combination of existing figures and emerging actors was identified according to the roles they needed to cover. The new contributions have been mainly shaped on the basis of the envisioned technological disruptive solutions, paving a multidisciplinary approach.

In conclusion, the research portrays a panorama of state-of-the-art and future possibilities in the field of immersive technologies and the related experiences, also focusing on their underlying design dynamics and uncovering the relevance of

multidisciplinary perspectives. The findings reported intend to facilitate the identification of actionable and fruitful trajectories to pursue in the development of the Artcast 4D research project.

Research Goals

Introduction and research questions

This document presents the research conducted within the first work package (WP1) of the European project Artcast 4D, which aims at "Exploring the Potential of Immersive Technologies". In particular, this reports the results of T1.2, on the "Interdisciplinary analysis of the immersive technologies and cross-sector applications", led by Politecnico di Milano with contributions from EXODUS, MDLite, TBG, Uinversité Paris-Saclay, CERTH, CulturaLINK, and IFAAR.

The investigation aims at understanding the concept of immersion, immersive technologies and experiences, as well as what is needed to design, develop, and deploy them. In particular, it proposes interdisciplinary perspectives to the analysis of the subject matter by considering different fields of application of immersive technologies (even though the artistic and cultural ones remain the most relevant for the research), the diversity of the competencies needed to design and develop immersive experiences, and the viewpoints of multiple professionals.

Specifically, to encompass theoretical and practical comprehension, the objective has been articulated in four main research questions that guided the research.

RQ1: How does the scientific literature define the concept of immersion enhanced by digital technologies?

Preliminary, a foundational and shareable definition of the concept of immersion, immersive technologies, and the functional elements to identify and assess them (Keys of immersion) have been investigated through a systematic literature review.

RQ2: How are immersive experiences currently conveyed?

Then, a practical understanding needed to complement the theoretical one (addressed in the previous RQ), observing how immersive installations, exhibitions and, more generally, experiences are characterised in concrete examples. This transition from theory to practice also allowed a translation of the previously identified essential concepts (e.g., Keys of immersion) into a functional means to recognize and compare the immersiveness of different experiences, thus their effectiveness for this purpose.

RQ3: How are immersive experiences currently developed?

A further step of analysis involved a deeper investigation of immersive installations, exhibitions, and experiences, looking at the design processes, the actors involved,

and the technologies and tools used as relevant information to gather for the development of the Artcast4D solution.

RQ4: How might immersive experiences evolve in the future in the artistic and cultural fields?

Finally, a foresight workshop activity involving different professionals and disciplinary perspectives was intended to identify possible future trajectories to infer gaps and opportunities in relation to the current situation and trends.

Overall methodology

To address the research questions and meet the aim of the investigation, different research activities have been undertaken, starting from a general understanding at a theoretical level and moving on to more practice-related issues that could ultimately inform the development of the Arcast4D solution. In the following the research activities and objectives are presented with reference to the chapters that discuss them.

Chapter 1: Definition of Immersion and Immersive Technologies

The first chapter mainly addresses RQ1 (*How does the scientific literature define the concept of immersion enhanced by digital technologies?*).

To obtain a more precise understanding of immersive technologies and how they can be exploited to foster immersive experiences, the research started with a thorough analysis of the concept of immersion. A literature review encompassing different disciplines has proven instrumental. It focused on exploring existing scholarly work related to immersion and immersive technologies. By analysing a wide range of publications, including academic papers, books, and reports, the project team aimed to identify the fundamental components and characteristics of immersive experiences and technologies as discussed in the literature.

As a result of this preliminary theoretical investigation, a comprehensive definition of immersion, a declination of the current state of immersive technologies, and the identification of five key features to identify and appraise immersive experiences – or *Keys of immersion* (*presence, engagement, sensory involvement, embodiment,* and *isolation*) – were qualitatively inferred from a coding and mapping activities.

Chapter 2: History of Immersive Technologies

A grey literature research has been conducted to add a historical perspective to the understanding of the matter at hand. The inquiry into the evolution of immersive

technologies was twofold. On the one hand, it was reported in relation to different fields of application while, on the other, it was depicted according to diverse technological categories. It relates to both RQ1 and RQ2. Indeed, it portrays the steps that brought to the current conception of immersion and immersive technologies from a theoretical perspective and shows their practical repercussions as they are reflected into everyday life.

Chapter 3: Case studies collection and analysis

RQ2 (*How are immersive experiences currently conveyed?*) has been more extensively investigated by focusing on the practical application of immersive technologies and related experiences. For this, the analysis of real-world examples was deemed necessary.

A diverse range of case studies of immersive installations and experiences has been collected with the support of the consortium partners who were engaged via an online questionnaire. 57 case studies have been firstly analysed and mapped according to their characterising features as emerged from the Google form responses (retrieved by the respondents from information publicly available online). Subsequently, they have been assessed based on the Keys of immersion previously defined to understand their immersiveness and classify them to identify the most interesting case studies for the research.

Despite the limitations of the study (relying on the expertise and perspectives of the partners who contributed to the composition of the sample set, and non compliant with statistical significance), this activity allowed to get a snapshot of the current panorama of immersive installations and experiences and helped identify information gaps for further investigation.

Chapter 4: Deepening the investigation of immersive case studies

To deepen the understanding of immersive experiences and installations also from an operative perspective and implications, RQ3 (*How are immersive experiences currently developed?*) aimed at gathering information that usually are not in the public domain but are essential components of the object of the research, and thus for the Artcast4D project. For this reason, a more qualitative method has been adopted and online semi-structured interviews have been conducted with the creative teams that have worked on the case studies that emerged in the previous step of the investigation. More specifically, they prompted fine-grained explanations of the design processes, including a comprehensive overview of the actors involved, the tools employed, and the values and pain points encountered. This ultimately informed the researchers about the inner dynamics characterising projects for immersive experiences, bringing to light wide-ranging competences, multiple disciplinary perspectives and varied team composition needed to develop these solutions.

Chapter 5: Future Backcasting

After depicting some trends, features, and possible gaps in the current application of immersive technologies, the research moves to a foresight activity to identify the most promising opportunities for the future of this field.

A workshop activity was conducted, bringing together relevant stakeholders with multidisciplinary backgrounds and perspectives, and aimed at envisioning future immersive experiences. The purpose of the workshop was to infer valuable trajectories for the future implementation of immersive technologies in artistic and cultural environments, particularly concerning the evolution of technological solutions, interaction modalities, experiences characteristics, professional figures and competences to achieve this. The last point being of particular significance for the study.

Chapter 6: Discussion

A final discussion concludes the report of the research activities. In this chapter, the research group provides an in-depth analysis of the elements discussed throughout the entire report. Multiple perspectives are considered, and the conclusions drawn from various chapters are reported. This comprehensive examination allows for an overview of the topics addressed and provides a synthesis of the findings presented in the report.

Annex

In support of the report, a conclusive section includes an integral representation of the questionnaire and the sheets synthesising all the case studies of immersive installations and experiences analysed (referred to in chapter 3).

1 Definition of Immersion and Immersive Technologies

1.1 Introduction and methodology

The concept of immersion has been explored within the academic community over the years and can vary depending on the theoretical and disciplinary perspective adopted.

In 1994, Milgram and Kishino introduced the concept of a *virtual continuum*, stating that immersive experiences exist on a spectrum ranging from the physical to the virtual and putting the bases for virtual and augmented reality research and development (Milgram & Kishino, 1994). Studies such as the one conducted by Slater and Wilbur (1997) explored the effect and perception of immersion considering virtual reality technologies. Bailenson et al. (2005) investigated the psychological impact of immersive virtual experiences, improving the understanding of applications and potential implications of this technology.

Even if many scholars explored the concept of immersion, the increasing use and development of immersive technologies in recent years is bringing more attention to the question: what are we referring to when we talk about "immersion"? What are the criteria and characteristics that lead us to understand which role new technologies play in relation to immersion?

The research aims at understanding how the concept of immersion has been addressed in the literature so far and which are its constituent elements. To reach this objective, a systematic literature review has been conducted by adopting the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines (Wittorski, 2012). These guidelines provide a standard methodology that allows replicating the literature review process.

The first step of the systematic literature review regarded the definition of the search criteria, made by creating two different queries, which include the words "immersive", "immersive technology" and "definition". The queries have been then searched in the online database SCOPUS, by selecting the article title, abstract, and keywords field. SCOPUS has been used as the research database mainly because it is an extensive multidisciplinary database covering published material both in the humanities and sciences.

The defined queries – (*immersion AND definition*) and (*immersive AND technolog* AND definition*) – respectively resulted in 636 and 240 papers. To filter them, some some exclusion criteria were identified, specifically: availability of the full-text, English language, and publication ranging from 2013 to 2022.

Although the concept of immersion has been widely used in scientific literature since the 1980s and the 1990s, also due to the advent of virtual reality, the systematic review was limited to the last ten years to get a contemporary overview. Indeed, our focus was on exploring how technological advancements have permeated the definition of immersion and how this is currently conceived.

After this first round of exclusion, the remaining 155 papers mainly included journals related to technical and applicative fields of Computer Science and Engineering. Then, the results were further filtered by reading the title and the abstract and removing the papers that were not pertinent to the research purpose. More precisely, studies that did not specifically address immersive technologies were discarded, such as those that discussed immersion in chemistry, referring to the concept of immersing substances in water. Finally, the remaining 33 papers were carefully read to assess their relevance for the investigation. During this process, it was noted that references that are milestones in the literature of this domain remained excluded from the identified set. Therefore, the research team retrieved these foundational resources through a snowball sampling, starting from the significant references encountered in the 33 papers analysed. Using this method, the team expanded the pool of explored studies to 46, including papers from various application fields and beyond the time limitations initially set.

To properly examine them, two cycles of coding were undertaken, supported by the software MaxQDA.

As the research objectives were clear and well defined from the beginning, a provisional set of categories could be used to steer the first cycle of hypothesis coding (Saldaña, 2009). In this method, some codes are listed prior to the analysis, directly reflecting what the researchers expect to find within the documents to be studied. Specifically they included: *Immersion Definition, Immersive Technologies Definition, Immersive Technologies History,* which directly inform this chapter of the report, then *Processes and Methodologies, Tools and Technologies, Stakeholders, Users and Interaction Modalities, Fields of Application,* and *Future Developments* to provide insights for the following steps of the research.

In this context, to provide clarity on the terminology used by the research team in relation to *Technology and Tools*, the specific meanings assumed are depicted.

The term *technology* refers to the broader technological domains that were identified and explored as enablers of immersive experiences, such as Virtual Reality, Augmented Reality, Mixed Reality - Extended Reality technologies - Projections, Light systems, and others. Tools, instead, refers to the specific devices and apparatuses used in the practical implementation of the aforementioned technologies. This term includes equipment like Head-Mounted Displays (HMD), simulators, mobile devices, projectors, and other relevant tools that are employed to deliver immersive experiences to users.

Furthermore, while retrieving information on the predetermined categories presented, a second cycle of focus coding was also performed to pinpoint thematic clusters and similarities (Saldaña, 2009).

Finally, affinity maps of the significant topics highlighted were built to identify macro themes. These facilitated discussions on relevant research issues and contributed to guide the researchers toward a comprehensive definition of the concept of immersion based on keywords derived from the analysis and designated as "Keys of Immersion". As well, the investigation allowed elaborate clusters and descriptions of immersive technologies, as presented in the following.

1.2 Defining the concept of Immersion

Several scholars provided a definition of immersion, some focusing on specific characteristics of the phenomenon, others by observing the behaviours of the users involved in an artificial experience or environment.

This section presents the findings of the systematic literature review conducted to examine definitions of immersion in artistic and cultural experiences. The review encompassed both newly proposed definitions and established ones. The overview emerging from the researchers' analysis focuses on the affinities observed among the various definitions of immersion encountered. Specifically, the first paragraph compiles references identifying the concept of immersion as the shift of human focus from the physical to the artificial world. The second explores the concept of isolation as closely as closely related to and strongly characterising immersion. The third paragraph delves into the fundamental role of the human sensory system in perceiving immersion, as well as the impact of stimuli from the surrounding artificial environment on human senses. Ultimately, the section concludes by referencing different levels of user involvement in immersive experiences.

Toward the artificial world, shifting users' perception of presence

Curiously, in the 33 reviewed papers, the physical world seems distant and completely forgotten when articulating the concept of immersion. On the contrary, a strict relationship with an artificial dimension projecting the illusion of an alternate reality is variously portrayed as an essential element of an immersive environment.

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." By using the word *inclusive*, the scholars define how much the physical environment is cut off from the user experience in the immersive environment. As well, Zhang (2020) refers to immersion as "sensory and perceptual experience of being physically located in a non-physical, mediated, or simulated virtual environment".

Moreover, in the context of imaginary or technology-mediated environments, Sas & O'Hare (2003), emphasize the concept of "shifting of focus of consciousness": the user in a physical environment shifts the attention to a different reality.

J. Murray (1997) defines 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". In addition, Zhang draws attention to the concept of shifting the focus of attention by defining immersion as a "transcendental experience of being physically shifted into the virtual space". "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" (Zhang, 2020). The author also defines the crucial role of senses in translating the focus from the physical to the artificial world.

Overall, the literature review revealed an inevitable convergence between the virtual realm and the current attempts to define immersion when technology is involved. Of course, this might depend on the specific domains and timeframe on which the research is limited. However, it denotes the strong influence that recently popularised technologies have on the definition of immersive experiences, overshadowing more direct and natural conceptualizations on the issue.

Concept of isolation

Some of the analysed papers report how a transposition of attention from the physical world to the artificial one occurs in an immersive situation, introducing the concept of isolation. For example, Lidwell et al. (2010) state that the "awareness of the real world" is lost. Turner et al. (2016) connect the concept of isolation to the technological component of the immersive system. They define immersion as "the degree of technologically mediated sensory richness that facilitates isolation or decoupling from the real world." Spence et al. (2017) also define the concept of immersion as "a range of internally perceived states [...] that focuses the participant's attention to the exclusion of everyday concerns." The authors additionally link concepts such as involvement, multi-level treaty, participant attention, and isolation from the real world.

Overall, the user's sense of isolation from the physical world, experiencing a complete or partial focus on the artificial environment, appears as inevitably intertwined with the perceived immersiveness. This feeling of detachment from the tangible world plays a crucial role in intensifying the immersive experience and deepening the user's sense of presence within the virtual realm.

Despite this is a strong and arguable position, this research is aligned with the findings that have emerged from the literature review, acknowledging the fact that the technologies and tools that are currently employed to foster immersive experiences usually tend toward the isolation of users.

Human sensory system and artificial stimuli

Although the concept of immersion appears to rely unavoidably on a virtual dimension, a reconnection with the physical one is recognized by the scholars, who emphasize the critical role played by human sensory and perceptual experience. This aspect can also be affected by the technological level of the immersive system.

On the one hand, the perception of the immersive environment can be experienced as an effortless process. Sweetser and Wyeth's GameFlow model of enjoyment in video games (2005) speaks of 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."

On the other, a sensation related to a physical perception and verbs such as "feeling surrounded", "enveloped", and "immersed" are found in literature as elements characterising the phenomenon of immersion, even though it is set in an artificial environment. Josephine Machon (2013) emphasizes this concept by declining immersive systems as "systems that generate a three-dimensional image that appears to surround the user."

Murray (1997) defines immersion as "the sensation of being surrounded by a completely other reality". Biocca and Delanay (1995) emphasize the perceptual phenomenon by describing immersion as "the degree to which a virtual environment submerges the user's perceptual system."

Enveloping stimuli and human perceptions also reconnect to Palmer's studies (1995), in which immersion is defined as "the degree to which users of a virtual environment feel engaged, absorbed and encompassed by the stimuli of the virtual environment.".

Zhang (2020) defines immersion in a virtual environment as a technological system that "engulfs the senses." West et al. (2015) report a "sensory augmentation" when talking about the interaction between material reality and interaction with digital data in the context of VR and AR technologies. The senses involved in human-environment interaction are multiple, and Sommer et al. (2020) underline that "full immersion addresses all human senses."

The sensorial environment encountered by the user plays a key role in shaping the perception of immersion. The stimuli received through various sensory channels, such as visual, auditory, tactile and other sensations, significantly influence the user's immersiveness. The quality and fidelity of these sensorial inputs and the relative "weight" of some of them (e.g., sight v/s stance, sight v/s acceleration, etc.) contribute to creating a more immersive and realistic experience, enhancing the overall sense of presence within the virtual environment and isolation from the tangible one, and encouraging engagement and embodiment. From the literature case studies related to the use of sensorial stimulation in immersive environments could be found (Pietroni & Antinucci, 2010).

Different levels of engagement and embodiment

The analysed papers also depict different levels of immersion that a person can feel based on how much the interactions with and within an immersive environment are able to generate involvement.

As Spence et al. (2017) reported, the sense of immersive engagement happens at cognitive, emotional, and physical levels. Slater and colleagues emphasize the physical dimension, speaking of immersion as "sensorimotor contingencies," defined in turn as "physical actions required within a specific environment to perceive and interact with a given environment" by Witmer and Singer (1998).

Buttazzoni et al. (2020) introduce "place immersion" as organised into several domains: neuro-spatial, psycho-spatial, and socio-spatial. Immersion is recognized as an "embodied process of an effortless experience," linked to "multiple influences of environmental context, cognitive factors, and relational activities" (Buttazzoni et al., 2020). Witmer and Singer (1998) also describe immersion as the reaction to an environment "which causes the participant to be enveloped by and interact with an environment that provides a continuous stream of virtual and haptic stimuli and experiences", highlighting the continuous, rich dimension of physical and digital stimuli typical of the immersive environment.

Even though multiple interpretations have been encountered, the macro themes extracted from the literature review converge on denoting the totality that characterise the concept of immersion. In this context, the research group has emphasized engagement as a critical factor in determining the user's level of focus within the immersive experience, encompassing both cognitive and emotional dimensions. Additionally, embodiment pertains to the extent of interactivity experienced by the user within the immersive environment, involving them in various ways.

1.2.1 Immersion definition and Keys of Immersion

Based on the findings reported in the previous section, here, a synthetic definition, encompassing the traits and characterising elements recognized by various scholars in the last ten years is offered.

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*".

In the provided definition, we underline the importance of human sensoriality and the stimuli given by the artificial environment surrounding the user, superimposing on those from the physical realm. The users' attention is totally shifted, and they are completely

engaged (cognitively, emotionally, and physically) in the interaction with the artificial dimension in which they are immersed.

From the analysis of the literature, synthesized in the given definition, valuable items could be extrapolated to identify the distinctive traits of immersion, reported as *Keys of Immersion*.

The *Keys of Immersion* refer to recurring elements related to the concept of immersion and include:

1. Presence
2. Engagement:
    2.1. Cognitive level
    2.2. Emotional level
3. Sensory involvement
4. Embodiment
5. Isolation

The next session, presented as a glossary, further explores and defines each *Key of Immersion*.

1.2.2 Keys of Immersion

Presence

Presence is a term often mentioned alongside the immersion concept and is sometimes used interchangeably. Slater et al. (2009) and Heeter (1992) refer to it as the feeling of being inside the environment in which one is immersed. For Cummings and Bailenson (Cummings & Bailenson, 2016) greater immersion is generally considered to increase presence. The higher the perception of presence in a specific environment, the higher the immersiveness felt by the user. Indeed, a direct correlation exists between the perception of presence within a particular environment and the immersiveness experienced by the user: when users feel a strong sense of presence, they become deeply engrossed in the artificial world, leading to a heightened feeling of immersion.

Engagement

As reported by O'Brien and Toms in their article (2018) "multiple studies of engagement have described it according to different characteristics, such as media presentation, perceived user control, choice, challenge, feedback, and variety. Cumulatively, these attributes demonstrate the physical, cognitive, and affective components of user experiences." Their definition of engagement is articulated as "a quality of user experiences with technology that is characterised by challenge, aesthetic and sensory appeal, feedback, novelty, interactivity, perceived control and time, awareness, motivation, interest, and affects." Expanding on these established definitions, a relationship emerges between user engagement and the perceived immersiveness. Notably, *cognitive engagement* concentrates on the conscious level of user involvement, where active participation and mental focus contribute to the overall immersive experience. Conversely, *emotional engagement* accentuates the subconscious aspect of the encounter, delving into the user's emotional responses and feelings that might not be readily apparent or consciously acknowledged.

Sensory involvement

As illustrated in the previous section, *sensory involvement* plays a key role in an immersive experience. Naef et al. (2022) report how the level of sensory immersion seems greater, as much as the alignment between the real and virtual environment is increased through technology that allows an effective sensory replacement. Creating this strong association enables the possibility to influence the sense of presence inside the virtual environment. *Sensory involvement*, as a key aspect of immersion, pertains to the interaction between the human senses and the stimuli presented by the artificial environment. It encompasses the engagement of various sensory modalities, such as vision, hearing, touch, and even proprioception, to create a holistic and immersive experience for the user.

Embodiment

Embodiment is defined as being surrounded by simulated sensorimotor information in mediated environments that create the sensation of personally undergoing the experience at that moment (Ahn, 2011). Embodiment can be identified as involvement occurring on an identity level, focusing more on a human inner perception rather than on the external relationship with the environment, influenced by the level of interaction within the experience. Embodiment allows users to not only observe but also actively participate and manipulate the virtual environment, which plays a significant role in enhancing their overall sense of immersion. Through embodied interaction, users experience a sense of agency and control, strengthening their emotional engagement and cognitive investment in the experience.

Isolation

Isolation from the concrete world is defined in literature as a positive connotation for an immersive experience because it enhances the shift of focus of the user from reality to an artificial environment. More specifically, Turner et al. (2016) define isolation as a direct consequence of the phenomenon of immersion, considering it as "decoupling from the real world." This isolation serves as a crucial phenomenon to minimize distractions and external influences, enabling users to be more mentally and emotionally engaged in the artificial environment. By embracing this isolation, users are able to explore, interact, and experience the artificial environment decoupling from the concrete one.

1.2.3 Discussion and limitations

The definition of immersion has been the result of the conducted analysis of the literature. Nevertheless, the provided definition presents some limits because it does not refer to multidisciplinary fields of application but mainly to the disciplines of Computer Science and Engineering to which the analysed papers pertain.

Indeed, the concept of immersion can also be considered an individual's psychological state. Murray (2017) states that immersion is a metaphorical term derived from the physical experience of being submerged in water and that we seek the same feeling from a psychologically immersive experience. Immersion is a crucial recurrent concept in the narrative as well.

Adam and Rollings (2006) conceptualised immersion in a story as "the feeling of being inside a story, completely involved and accepting the world and events of the story as real." Since the 1950s, artists have also explored the potential of technology for this purpose. For example, the artist Myron Krueger (1983) coined the term "Artificial Reality" to describe a new kind of installation in which the physical body of the user affects the development of the meaning of the work of art.

Contemporary artists create immersive environments that allow audiences to escape to other realms and experiment with authentic emotional responses (Mitchell, 2010).

1.3 Identifying Immersive Technologies

Different technologies have been identified in the literature as connected to the immersion concept and by presenting various degrees of immersion. These technologies are defined as immersive technologies. From the systematic analysis of the literature, it emerged that in the last decade, in the field of Computer Science and Engineering, mainly Virtual Reality (VR) and Augmented Reality (AR) are reported as immersive technologies. VR and AR technologies are usually associated to the

Virtual Continuum of Milgram and Kishino (1994), which exists on a mixed reality spectrum (MR) (Fig. 1).

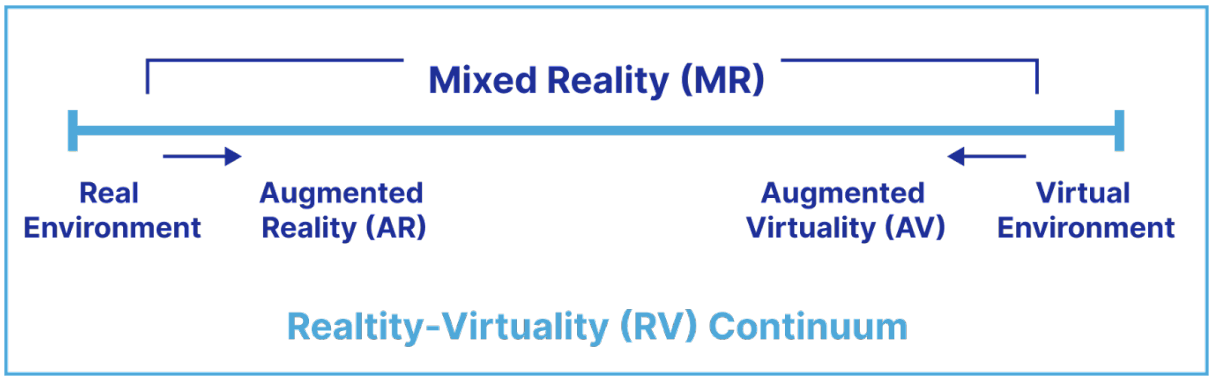


Fig. 1: Virtual Continuum as depicted by Milgram and Kishino (1994).

In the Virtual-Continuum, Augmented Reality (AR) is positioned close to the Real Environment, since virtual objects overlay on the tangible-world substratum, while Augmented Virtuality (AV) is closer to Virtual Environment, since tangible objects/contents are displayed on a virtual substratum. As mentioned by Lohre et al. (2020) on the spectrum, VR provides entirely virtual worlds, AR provides virtual image overlay onto real-world interactions, and MR encompasses the breadth of application between the two.

In recent years, AR, VR, and MR have often been associated with the broader term of Extended Reality (XR) technologies. As stated by Zhang (2020), XR technology is a concept that incorporates VR, MR, and so AR and suggests a simulated and imaginary reality that is dictated and extended by our physical reality.

In addition, one of the concepts related to XR technologies cited by some researchers is that of Metaverse, which allows users to permanently access online content using XR technologies (Pimentel et al., 2022). A first definition of the Metaverse is given by Stephenson (1992) as "a world where humans as avatars interact with each other and with software agents in a 3D space that reflects the real world". In their study, Lee and Kim (2022) analysed several definitions of the Metaverse by different authors and provided a comprehensive one. For them, the Metaverse is "the permanent, immersive mixed-reality world (including the virtual world as the parallel world of the real world or the real world of data being augmented) where people and people, people and objects can synchronously interact, collaborate, and live over the limitation of time and space, using an avatar, the immersion-supporting devices, platform, and infrastructure."

Starting from these considerations on immersive technologies, the following sections present definitions of VR, MR and AR derived from the systematic analysis of the literature conducted on papers published in the last ten years. Moreover, explicit links to the *Keys of Immersion* defined in the previous chapter are highlighted.

1.3.1 Virtual Reality

The term Virtual Reality was first coined by Jaron Lanier in 1986. This concept changed over the years, influenced by new technological advancements. In the literature analysis, different definitions of VR have been framed, and many scholars refer to some aspects that can be associated with the previously defined *Keys of Immersion*. In particular, the most recurrent terms encountered are *presence, engagement, sensory Involvement.*

VR is associated with presence by Steuer (1992), who suggested a correlation between VR and the concepts of *presence* and *telepresence*, defined as the sense of being in an environment generated by a natural or mediated means. The Department of Defense (2018) talks about a sense of presence from the objects in the virtual environment. Benoit et al. (2015) declare that VR "can provide the sensation of physical presence in places representing real or imagined worlds."

The *engagement* concept is underlined in several studies by stressing the interactivity aspects and the user experiences in VR environments. Bisson et al. (2007) define VR as a real-time and interactive simulation. McCoy and Stone (2001) present VR as a technology set that allows people to interact in real time with digital databases. VR is compared to an individual experience with many stimuli through interaction by Barbosa et al. (2019). Optale et al. (2010) connect the interactivity of VR technologies with the visual, tactile, and kinaesthetic components of perception, while user interaction in VR is made through multiple sensory modalities also for Hsieh et al. (2018).

Other scholars refer to the *sensory involvement* concept**.** Sommer et al. (2020) report that visual, audio, and haptic senses are involved in VR applications.

In the Merriam-Webster's online dictionary, VR is described as a technology experienced through sensory stimuli such as sights and sounds. Kilmon et al. (2010) and Mantovani et al. (2003) agree on defining visual and auditory feedback as key features of the VR environment to let the users feel completely immersed into the virtual environment. Lohre et al. (2020) relate the head-mounted display and the controllers (both technological items related to the use of VR technology) with the visual and auditory cues on one side and with haptic feedback on the other hand. Dos Santos Mendes et al. (2012) define VR as a "computer-based technology providing a multisensorial environment."

Concerning the concept of the surrounding environment**,** many scholars point out that VR technology is generated from a computer device to create a three-dimensional environment. Schoeder (1996) defines VR as a computer-generated display that allows the user to have a sense of being present in an environment in which she can interact. This environment is defined as different from the one the user is in. Glännfjord et al. (2017) state that VR is a computer-generated simulation that creates a realistic-looking world, while for Levy et al. (2016), VR involves the creation of an interactive computer-generated, three-dimensional environment. The INACSL Standards Committee (2016) defines VR as a "computer-generated reality," here

again underlying the computer-generation nature of the technology, "which allows a group of learners to experience various auditory and visual stimuli."

1.3.2 Augmented Reality

The term Augmented Reality was first coined by Tom Caudell (1992) and discussed by many scholars over the years. In their study, Ardiny and Khanmirza (2018) analysed the Milgram et al. (1995) Virtual Continuum, previously cited, to provide a definition of AR. Their proposal described it as "an interactive experience in the real-amsworld 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 et 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. (2015) 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 relate to 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; Nikhashemi et al., 2021; Rauschnabel et al., 2019; Smink et al., 2019; Yim et al., 2017). 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.

1.3.3 Other technologies and tools for immersive experience

Certain technologies are only mentioned in relation to specific application case studies, making it challenging to locate prior studies and papers on these technologies. Nevertheless, the authors deemed it worthwhile to include them in this report in order to offer a more comprehensive perspective on the available immersive technologies and tools. A short definition of each is provided in the following.

Head-mounted display (HMD)

Head-mounted displays (HMDs) are devices that the observers can wear directly on their head, which present the shape of goggles. By using these devices, digital/virtual information is given through monitors covering the normal visual field (Milgram & Colquhoun, 1999). HMDs could cover both VR and AR technologies: in the first case, the content shown is projected to the user through two lenses inside the visor. In the second case, the HMD works as a whole transparent lens through which users can see the tangible world enhanced with AR projection, presented on the lens itself.

Cave Automatic Virtual Environment (CAVE)

Cave Automatic Virtual Environment (CAVE) has been defined by Manjekar et al. as a fully immersive virtual reality environment that simulates controlled contexts (Manjrekar et al., 2014). The CAVE is usually a cubic room with sides made up of rear-projection screens (Muhanna., 2015). Being inside this cubic immersive space, the users can also interact with the immersive content.

The system was invented in 1992 by a group of researchers at the Electronic Lab of the University of Illinois (Cruz-Neira et al., 1992).

Projections

The projection technology for immersive installations/experiences presents many practical implications. Considering the grey literature and analysing some aspects of the technology used in several case studies (Maldovan et Messner, 2006; Maldovan et al., 2006), the authors assume that projection for immersive environments uses a projector to allow digital audio-visual content to be projected on surfaces or objects in the physical environment. Some studios and artists also use the technology of 3D mapping on a building, specific environments or 3D geometries shaped in space to better fit the audio-visual content (video or image not necessarily with an audio system on it) on the physical space.

Video 360°

Li et al. (2020) describe the so-called 360° video/image - also known as panoramic, spherical or omnidirectional - as a new multimedia type providing an immersive experience for the user.

The image 360° content, with *QuickTime VR* as a commercial example from Apple.inc, surrounds the viewer, offering a panoramic vision different from the classic 2D representations, which exploits just a limited flat planar surface. A significant enhancement of this approach, originally termed *QT-VR 3.0* by Apple, was the shift from still images to video clips.

This surrounding characteristic is given by the audio-visual content, which relies on a sphere covering the 360×180° observers' viewing range.

Body tracking tools

As Watada et al. (2010) report, in a more general way, "tracking can be defined as an action which can estimate the trajectory of an object in the image plane as it moves within a scene." Several different methods can be used to track a human body through a digital system: we can say today, "Visual tracking of human body movement is a key technology in a number of areas" (Huang et Huang, 2002). In immersive environments and installations, the body tracking technology can record the position and movement of the users and transmit this information to the digital/virtual system, with the enhancement of several interaction modalities.

Haptic devices

Regarding haptic technologies, Sreelakshmi and Subash (2017) defined them as "the science of applying touch sensation and control to interact with computer-

developed applications" Steinbach et al. (2018) define haptic devices as mechatronic devices that deliver force feedback to the user. These devices allow users to experience the material sensation (e.g. velvet) and the "force" or physical presence of a virtual object (e.g., surgical instruments for operations, fragile or soft object manipulation), guaranteeing better control and interaction through tactile feedback.

Audio systems

Valbom and Marcos (2005) recognized sound as a vital aspect in creating ambiance and emotion. Their study presents the necessity to match it with new interaction paradigms, such as gesture-based actions and 3D visual contents, in immersive environments.

Typical enhancements in this field were THX audio specification, mainly addressing movie and IMAX theatres plus holophonic audio systems.

From the literature, we declare that the principal function of immersive audio systems is to synthesize, manipulate, and render sound fields in real-time (Kyriakakis, C., 1998).

2 History of Immersive Technologies

To augment the comprehensive understanding of immersive technologies, a historical perspective has been incorporated to trace the evolution of this subject. The investigation encompasses two main facets. Firstly, fundamental advancements facilitating immersive technological innovations over the past decades have been discerned. These significant achievements are identified in relation to various fields of application, which were derived from the coding activity of the preceding literature review. Subsequently, the impact and progressive strides of immersive technologies within these fields are expounded, explored through a more extensive analysis of grey literature.

Secondly, pivotal historical dates pertaining to diverse technologies and tools are presented, organised both categorically and chronologically. These dates are compiled into a graphic timeline, facilitating a concise visual representation of the progression. This historical tracing has been further substantiated by an exhaustive examination of the grey literature, enabling the identification of critical milestones in the development of immersive technologies.

2.1 Evolution of immersive technologies per application field

Over the years, immersive technologies have found application in various fields. Fig. 2 highlights significant events where immersive technologies have been adopted throughout different disciplines. They have been relevant in scientific sectors like medicine as a more specific endeavour of application. Additional domains in which they found purpose and meaning include gaming, education, as well as arts and cultural heritage, of interest for this project.

Medicine

Immersive technologies have garnered recognition as highly impactful tools within the medical and healthcare fields for various reasons. Firstly, they can be instrumental in augmenting the performances of medical operators by providing digital assistance and facilitating the manipulation of 3D data, even from remote locations. Moreover, these technologies hold transformative potential in the realms of training and education within the medical field. They enable the creation and delivery of artificial content, offering immersive and realistic simulation experiences for medical students and professionals alike. By immersing learners in lifelike scenarios, these technologies facilitate experiential learning, enabling trainees to acquire practical skills and competencies in a safe and controlled environment (Dzyuba, 2021).

From a temporal point of view, some key dates resulted from the exploration. In 1980, the head-mounted display was introduced as a wearable device for VR visualisations in medicine, with a first step for immersive experiences in the medical field (Pantelidis et al., 2018). Ten years later, in 1991, the University of Colorado created the Visible Human Project, a pioneering massive online database containing human images and information, opening new possibilities for medical research and education (U.S. National Library of Medicine, n.d.).

In 1994, AR made its first appearance in cranial neurosurgery, being used as a tool to aid in surgical navigation, demonstrating its potential for medical applications (Jean, 2022b). In 2008, the NeuroVR platform, initially developed as NeuroTouch by the National Research Council of Canada, emerged as a leading VR system for neurosurgical training, illustrating its importance in medical training and simulation (Rosseau et al., 2013).

Art

Immersive technologies have forged a robust connection with the art field, opening up new possibilities and becoming innovative tools for artists to create groundbreaking artworks. The advent of Virtual Reality, Augmented Reality, projectors, and other immersive tools has significantly transformed the landscape of artistic expression, providing creatives with fresh avenues for exploration.

In 1974, it was presented to the public the artwork *Videoplace*, from Myron W. Krueger, an interactive installation which combines a participant's live video image with a computer graphic world. In *Videoplace*, a participant can interact with other participants in remote locations through a projected image of herself on a video screen. A single participant can also interact with graphic objects and creatures on a screen, which appear to react to the movements of the participant's image in real-time. This could be recognized as one of the first attempts of VR to be used as a tool in the art field. (Bokyung, 2016)

From the findings of the literature review, a notable date signifying the introduction of Augmented Reality into the art field is the year 1994. During this time, Julie Martin's augmented reality theatrical play, *Dancing In Cyberspace*, captivated audiences by showcasing performers, dancers, and acrobats seamlessly interacting with virtual objects. (Shavel, 2023). Another interesting example concerning Augmented Reality technology is related to *WeARinMoMA* with is an exhibition created by Sander Veenhof and Mark Skwarek in 2010 (Kaganskiy, 2010) This provocative exhibition aims at showcasing augmented reality art in its proper context, the MoMA NYC contemporary art museum. At the same time, this project also consisted in an 'art invasion', since the museum was not involved in the project.

Concerning Virtual Reality instead, an interesting project is represented by *Real Violence*, a VR experience created by Jordan Wolfson was exhibited at the Whitney Biennial in 2017. The art exhibition is interesting since it exploits VR technology to question the politics of 'empathetic' immersion (Wolfson, 2030).

Cultural heritage

Immersive technologies offer cultural heritage powerful tools to significantly enhance visitors' experience and the curator or museum space's perspective. Within the realm of art, these technologies present a multitude of new potentialities, revolutionising the way cultural items are interacted with and appreciated.

Firstly, immersive technologies empower visitors to engage with objects and artworks in an enriched and interactive manner. Secondly, these technologies enhance accessibility, making cultural heritage more inclusive and accessible to diverse audiences. People with physical disabilities or geographical constraints can now access museums and cultural sites remotely, breaking down barriers and expanding the reach of art and history. Then, immersive technologies are recognized to offer the possibility to explore and visit new places and times. Moreover, immersive technologies enable the reliving of past experiences, allowing visitors to step into historical events and experience them as if they were there, fostering a deeper understanding of history's impact on the present. Lastly, these technologies facilitate the reinterpretation of history (Jusseaux, 2021).

From the literature review, some dates have been found in order to present case studies into a timeline. In 1994, the concept of virtual heritage was introduced as a museum exhibit, with a 3D reconstruction of Dudley Castle in England as it was in 1550, emphasizing the application of VR in preserving and presenting cultural heritage (*The First Use [...] : History of Information*, n.d.). In 1995, the first international conference dedicated to the use of virtual reality for cultural heritage was held in Bath, GB, underscoring the growing interest in leveraging VR for preserving and promoting cultural artefacts. (Learning Sites, Inc., n.d.) In 1999, mobile AR technology made strides in the cultural heritage field through projects like *MARS* and *ARCHEOGUIDE*, showcasing the potential of AR for enhancing visitor experiences in cultural sites. (Vlahakis et al., 2001). Over the years VR and AR technologies have been implemented by Cultural Institutions to support the exhibition and create engaging experiences. Worth mentioning is the project called *Kremer Collection VR Museum*, created in 2018, which can be considered one of the first entirely virtual museums open to the public (The Kremer Collection, 2023). This project consists of a virtual recreation of a privately owned collection of about 70 artworks of Dutch and Flemish painters from 17th century. During the coronavirus pandemic situation, started in 2020, many museums had an acceleration in their digital transformation. In order to deal with closure and isolation, many museums created online free virtual tours with the aim of engaging visitors (Agostino et al., 2021).

Entertainment

In recent years, studies have observed a significant shift in the entertainment field, similar to the introduction of mobile devices in the early 2000s. The widespread adoption of immersive technologies, such as Virtual Reality (VR) head-mounted displays (HMD) and Augmented Reality (AR) applications, has reshaped the landscape of immersive entertainment experiences. With the increasing immersion and heightened sensory engagement that these technologies offer, users can now be more directly and deeply involved both cognitively and emotionally during their entertainment moments. This evolution has positioned immersive technologies as a game-changer within the entertainment industry (Lages, 2019).

The pivotal moment in the history of immersive entertainment can be traced back to 1991 when the Virtuality Group launched *Virtuality*, the first mass-produced VR entertainment system. This revolutionary introduction disrupted the entertainment industry and laid the foundation for further advancements in immersive experiences (*History of Virtual Reality - Virtual Reality Society*, 2020).

In more recent times, in 2016, the influential Pokémon franchise made a significant impact in the AR space with the development and release of *Pokémon GO*. This groundbreaking AR gaming application brought the potential of AR to the forefront, captivating a mass audience and exemplifying the ability to engage large user bases in gaming and entertainment realms (Javornik, 2016).

Industry

When discussing the implications of immersive technologies in the industrial field, it is essential to acknowledge not only their potential for promotional purposes but also their applications within the industrial processes. From a promotional perspective, immersive technologies offer significant benefits by enhancing the user experience when engaging with immersive touchpoints. However, another strong value of immersive technologies in the industrial context extends beyond promotion. Within the industrial working environment, these technologies can significantly improve efficiency and productivity. For instance, the integration of smart glasses for Augmented Reality (AR) content in maintenance activities allows workers to access relevant information hands-free in real-time. Similarly, immersive content delivered through Virtual Reality (VR) head-mounted displays (HMD) can revolutionise employee training programs in a safe and controlled environment. Moreover, immersive technologies enable enhanced team collaboration. Remote platforms that support immersive content, accessible through devices like HMDs, foster more seamless and engaging collaboration among workers, regardless of their physical locations (HeadApp, 2022). In addition, manufacturers could benefit from the overall platforms and applications useful for 3D modelling, sculpting, analysing models and so on related to the digital immersive world (Iec, 2018). Nowadays, companies such as Walmart, Bank of America, MGM, Albertsons, FedEx, JetBlue, GE, Sprouts, and Verizon are using immersive technologies inside their offices and daily working-routine (Joshbersin & Joshbersin, 2022).

In order to reach these possibilities, some key studies are valuable of mention. In 1993, *KARMA* (Knowledge-based Augmented Reality for Maintenance Assistance), the first project for maintenance applications which uses a see-through head-mounted display to display instructions about how to perform a task on a printer, was created (Oliveira et al., 2023). In 2004 Stuart Gooseet al. (2004) created an AR system that uses voice commands for helping industrial technicians in the inspection of an implant. Concerning AR technology for industrial applications, in 2007, it started also to be widely adopted within the CAD (Computer-Aided Design) models (Malta et al., 2023).

Education

Immersive technologies are often related to the term *immersive learning* while talking about these technologies inserted into the educational field. The immersive learning environment requires users/students to be immersed in a precise scenario related to the subject they are studying. Immersive technologies lead to two different approaches. The first is *presentation*, which represents the primary use in the context of teaching and learning. For instance, instructors or students can leverage VR or AR to deliver presentations on particular subjects, enhancing the learning experience with interactive visualisations and simulations. The second type is *exploration*. Here, VR and AR offer students and researchers the opportunity to do more than merely

observe and listen to educational materials; instead, they can actively engage and explore these materials up close (McIntosh, 2023).

Reporting some more historical data, in 1992, Louis Rosenberg developed the *Virtual Fixtures system*, one of the earliest AR systems utilised for educational purposes in the US Air Force's Armstrong Research Lab (Louis Rosenberg Develops Virtual Fixtures [...]: History of Information, n.d.).

By the year 2000, research studies led by Alessandro Antonietti and his team confirmed that VR could be beneficial for learning, highlighting its educational applications (Antonietti & Cantoia, 2000).

Between 2010 and 2020, VR integration in schools became increasingly widespread, as the use of VR expanded from PC-based systems to stand-alone devices, transforming the way education could be delivered.

These historical milestones reflect the continuous evolution and wide-ranging impact of immersive technologies across various fields, from entertainment and education to medicine and cultural preservation.

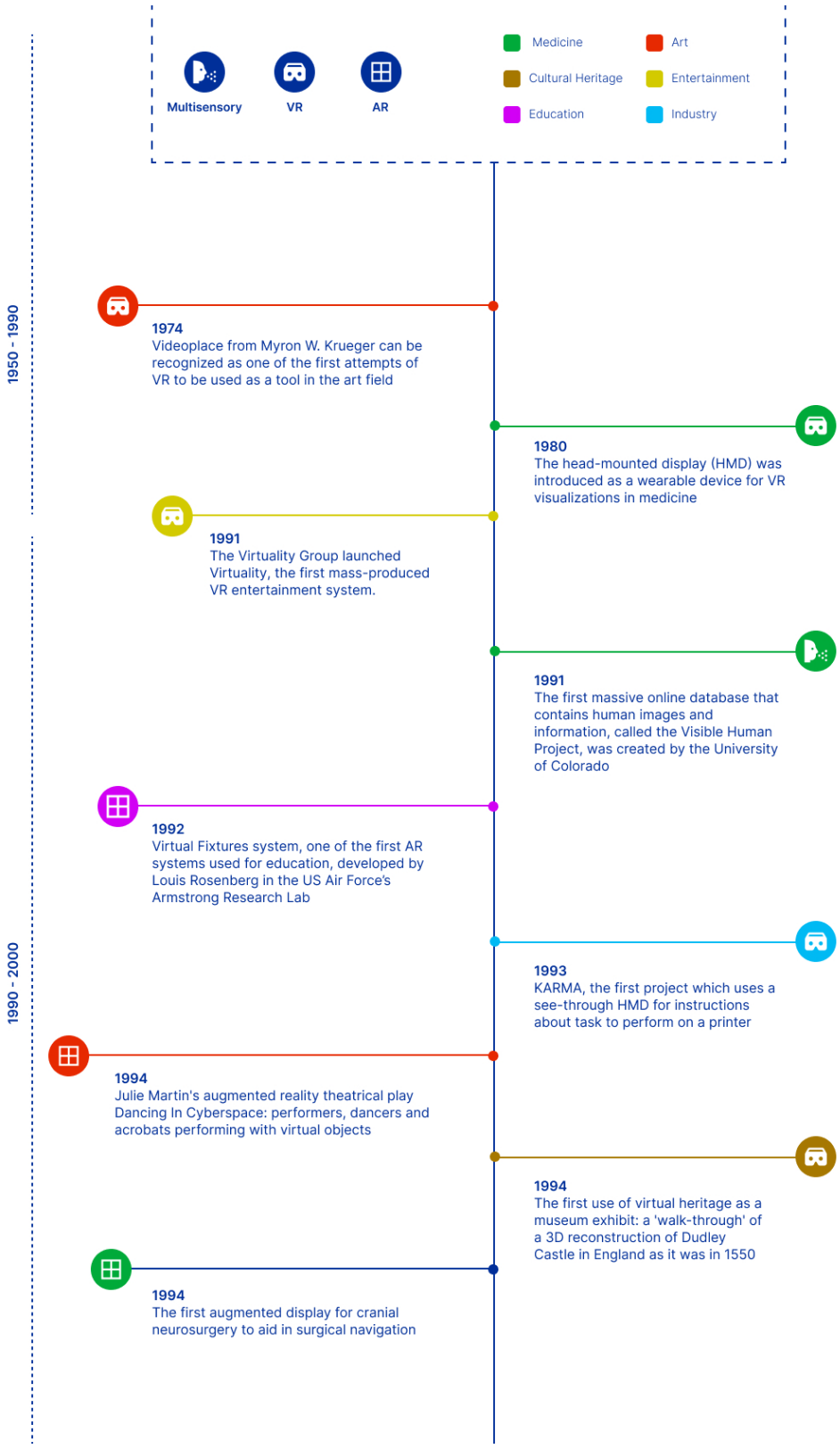

Multisensory
VR
AR
Medicine
Art
Cultural Heritage
Entertainment
Education
Industry
1950 - 1990
1974
Videoplace from Myron W. Krueger can be recognized as one of the first attempts of VR to be used as a tool in the art field
1980
The head-mounted display (HMD) was introduced as a wearable device for VR visualizations in medicine
1991
The Virtuality Group launched Virtuality, the first mass-produced VR entertainment system.
1991
The first massive online database that contains human images and information, called the Visible Human Project, was created by the University of Colorado
1990 - 2000
1992
Virtual Fixtures system, one of the first AR systems used for education, developed by Louis Rosenberg in the US Air Force's Armstrong Research Lab
1993
KARMA, the first project which uses a see-through HMD for instructions about task to perform on a printer
1994
Julie Martin's augmented reality theatrical play Dancing In Cyberspace: performers, dancers and acrobats performing with virtual objects
1994
The first use of virtual heritage as a museum exhibit: a 'walk-through' of a 3D reconstruction of Dudley Castle in England as it was in 1550
1994
The first augmented display for cranial neurosurgery to aid in surgical navigation

Fig. 2: History timeline of the application of immersive technologies in the fields of medicine, art, cultural heritage, entertainment, industry, and education.

2.2 Evolution of Immersive Technologies per category

The first key moment in immersive technology history is 1838, when Charles Wheatstone, Professor of Experimental Philosophy at King's College of London, developed the first stereoscope system: a device used for viewing a pair of separate images, different for right and left eye, in order to create a single three-dimensional image (King's College London, n.d.). This represented the first step in the 3D object awareness visualisation and can be recognized as the first step into immersive technologies development. Therefore, the experience of immersive content was first approached through sight but evolved in multiple directions.

The subsequent sub-paragraphs outline the evolutionary trajectory of various immersive technologies over time, distinguished by typology (namely multisensory technologies, virtual reality, augmented reality, haptic systems, and interactive surfaces). The most noteworthy steps are presented, and they have been highlighted for their demonstration of novel applications, market and technical innovations, initial research endeavours in respective fields, and unprecedented public presentations of new products and systems (Fig. 3).

Multisensory technologies (scent, tactile, sound, sight)

In the last century, technical innovations have focused on the involvement of multisensory stimulation, especially to create immersive experiences for entertainment.

For instance, several attempts have been made in the movie industry to merge sight and scent or to engage the public through immersive sound experiences.

In 1939, *Smell-O-Vision*, invented by Hans Laube, was presented. It was a system that released scents targeting individual seats in movie theatres and it was exhibited at the New York World's Fair (Brownlee, 2006). One year later, in 1940, the Disney film *Fantasia* presented surrounding sound technology in several scenes, enhancing the immersivity of the movie (Tibbs & Tibbs, 2023).

1952 marked the first appearance of spectacles with right and left eye colour filters in movie theatres to enhance the 3D effect with the movie *Bwana Devil*, American adventure B movie written, directed, and produced by Arch Obole.

In 1958 the integration of scent into movie theatres reported another attempt: *AromaRama*, designed by Charles Weiss to circulate vaporised scents around the room via the theatre ventilation plant (Nbr_Admin, 2014). Concerning olfactory stimulation, another solution emerged in 1960, when *Smell Brain* was implemented to automatically release a series of perfume bottles into the theatre (Montefiore, 2022).

In 1962, Morton Heilig created a multisensory simulator called *Sensorama*. Heilig intended to enhance a normal movie experience (stimulating sight by images and hearing by sound) by adding binaural sound, scent, wind, and vibration experiences. This invention was the first to encompass several senses to make the users feel more immersed in the experience. (*The Sensorama: One of the First Functioning Efforts in Virtual Reality: History of Information*, n.d.)

Back to auditory involvement, in 1976, Dolby Laboratories introduced the *Dolby Stereo,* an advanced audio system enhancing user perception with surrounding sound (Abreu, 2021).

Scent stimulation in movie theatres saw its return with *Odorama*, a cart with perfumes inside to scratch during different moments of the movie (Google, 2015).

In 2006 wave field synthesis technique approximated a real-world acoustic environment for the listeners (Ranjan, 2021). This was a big step for the audio field in relation to immersive experiences. The videogame industry actually steered the immersive technologies market toward innovations in the field. In 2006, Nintendo started to commercialise the Wii, the first console to bring motion-sensor controllers into popularity. And in 2010, Microsoft brought the Kinect to life, the first 3D motion capture system inside the domestic gaming field (*The Story Behind Nintendo Wii*, 2021; Jowitt, 2019).

2009 was the year of the first *4DX movie theatre* debuted in South Korea (*4DX | JH Movie Collection Wiki | Fandom*, n.d.).

2014 was also the year of *oPhone,* which transmitted scented messages via an app and two cylindrical contraptions (Stinson, 2014). In 2015, Visitors to Tate Gallery smelled *3D-printed scented objects* related to paintings (Volpicelli, 2015).

Virtual Reality

In parallel, experimentations with immersive technologies moved also towards Virtual Reality. One of the first steps toward Head Mounted displays (HMD) was made in 1961. The need to train soldiers in dangerous situations has led Charles Comeau and James Bryan to develop the *Headsight*. The system consisted of linking a remote camera to the user's head movement: this innovation let the soldiers see what was happening in the dangerous field without being physically present (*Sutori*, n.d.).

Later on, 1968 marked an important step for immersive technologies: Ivan Sutherland and his student Bob Sproull developed the *Sword of Damocles*, a system recognized as the first HMD technology developed in the immersive field. It supported a stereoscopic display that presented content generated by a computer program and updated according to the user's head position, orientation, and movements (*The Sword of Damocles: Early Head-mounted Display - CHM Revolution*, n.d.; Neeru, 2017).

In the same year (1968), the first HMD hardware was developed at the UNC University of North Carolina at Chapel Hill.

In 1980 it was the first time that an HMD was introduced as a wearable device for VR visualisations in medicine (Fourtané, 2019). This was a first step into the medical field, with the introduction of immersive technologies for enhancing scientific performances. A few years later, in 1984, NASA developed a stereoscopic monochrome HMD called *VIVED* – Virtual Visual Environment Display (*The Virtual Interface Environment Workstation (VIEW), 1990*, n.d.). While in 1987, Jaron Lanier, an American computer scientist, coined the term *Virtual Reality* (*Jaron Lanier : The Man Who Coined the Term Virtual Reality*, n.d.).

The VLP company in the Eighties invented the *Eyephone HMD*, which created a depth image for an immersive experience as HMD – the first commercially available VR devices (Vradmin, 2017).

In 1989, the Fake Space Labs launched *BOOM (Binocular Omni-Orientation Monitor)* into the market. This was a small box containing two CRT monitors that could be viewed through eye holes. The user could grab the box, keep it by the eyes and move through the virtual world, as a mechanical arm measured the position and orientation of the box (*Mechanical Tracking Device: BOOM From Fake Space Labs.*, n.d.).

In 1991, the Virtuality Group launched *Virtuality*, the first mass-produced VR entertainment system (Barnard, 2022). In the same year, *Visible Human Project*, the first massive online database containing human images and information, was created by the University of Colorado (U.S. National Library of Medicine, n.d.).

1992 was the year of *CAVE* - CAVE Automatic Virtual Environment. This was a virtual reality and scientific visualisation system. Instead of using a HMD it projected stereoscopic images on the walls of a room, which users could see by wearing LCD shutter glasses instead of the previous colour filtering technology. This approach assured superior quality and resolution of viewed images, and a wider field of view in comparison to HMD-based systems (*The CAVE Virtual Reality Environment (1992).*, n.d.). In 1994 virtual heritage was introduced as a museum exhibit. A 'walk-through' of a 3D reconstruction of Dudley Castle in England as it was in 1550 (*The First Use of Virtual Reality in a Museum or Archaeological Context: History of Information*, n.d.). In 1995 the first international conference dedicated to the use of VR for cultural heritage was held in Bath, GB (Learning Sites, Inc., n.d.), and virtual reality started to approach several fields, enhancing user interaction and immersion.

In 1999 Dresden University introduced the fresnel lens *Filter* to recreate a kind of 3D view on flat CRT screens.

In 2008 a leading VR system for neurosurgical training was presented: the *NeuroVR platform*, developed as *NeuroTouch* by the National Research Council of Canada (Sawaya, n.d.).

In 2012, Oculus company commercialised the Oculus Rift, an HMD visor for VR content fruition. This HMD company engaged Facebook attention, who acquired it into 2014, entering the Virtual Reality technology field (Chafkin & Leibovitz, 2015). Google entered this technology sector, too, and the big company commercialised *Google's Cardboard* in 2014, allowing usual smartphones to act like an HMD by being inserted into a cardboard box. In this way, users could interact with VR content through their own devices (VR, 2021).

In 2017, Facebook released the *Oculus Go* for VR. Concerning commercialised solutions, in 2019 Facebook took a step ahead of its competitors releasing *Oculus Quest*, the best VR HMD system with an affordable price for the public.

2021 was the year Facebook announced plans for its own Metaverse, with related huge investments. To stress its shift of focus, at the end of the year, Facebook changed its name to Meta. This same year, more than 85 million VR headsets were used in China, according to PWC (PricewaterhouseCoopers, n.d.; Frenkel et al., 2022). In the first part of 2023, Apple presented the Apple Vision Pro, innovative XR glasses, while in autumn 2023, Meta Quest 3 for virtual and mixed reality will be released, which is more comfortable to wear and offers a higher resolution and performance than the previous model. Apple's Vision Pro introduces an innovative controller to cater to the user's desired immersiveness. This controller, located on the visor, enables users to gradually transition from AR visualisation to a fully immersive VR environment by adjusting the knob. Additionally, Apple plays a crucial role in the product's communication, making the HMD (head-mounted display) accessible for everyday use by a wider audience, potentially integrating it into their daily routines.

Augmented Reality

In 1982, Thomas Furness at the US Air Force's Armstrong Medical Research Laboratories developed *the Visually Coupled Airborne Systems Simulator* – an advanced flight simulator. The fighter pilot wore an HMD that augmented the out-the-window view with graphics describing targeting or optimal flight path information (*A Pilot's Helmet … NARA & DVIDS Public Domain Archive Public Domain Search*, 2023).

In 1990, three years after the term VR was defined by Lanier, Tom Caudell, an employee at Boeing Computer Service Research, coined the term *Augmented Reality* (Mealy, 2018). In 1992, the *Virtual Fixtures system*, one of the first AR systems for education, was developed by Louis Rosenberg in the US Air Force's Armstrong Research Lab (*Louis Rosenberg Develops Virtual Fixtures, the First Fully Immersive Augmented Reality System: History of Information*, n.d.).

Julie Martin's augmented reality theatrical play *Dancing In Cyberspace* was presented in 1994. It involved performers, dancers, and acrobats interacting with virtual objects (*Sutori*, n.d.-b). Also in 1994, for the first time,an augmented display was

used for cranial neurosurgery to aid in surgical navigation in the medical domain (Lee & Stienen, 2019).

1999 was the year of the first adoption of *mobile* AR in Cultural Heritage with the *MARS* and *ARCHEOGUIDE* projects (Stricker et al., 2001). The new millennium opened in 2000 with *AR Quake*, the first AR videogame (*ARQuake - Wearable Computer Lab*, n.d.). In 2016 popular game *Pokémon GO* brought AR gaming to a mass audience (Staff, 2016). Microsoft later brought another step up into the field with Hololens in 2015. These are AR HMDs developed by a big tech company. In 2017 Apple developed its Augmented-Reality platform *ARKit* for iPhone. Google also entered the AR field in 2018 with its Augmented-Reality platform called *ARCore*. Next year, *Microsoft's Hololens 2* for AR was marketed (Goode, 2019; *Crea Nuove.* | *ARCore* | *Google for Developers*, n.d.; Heather, 2023).

Haptic systems

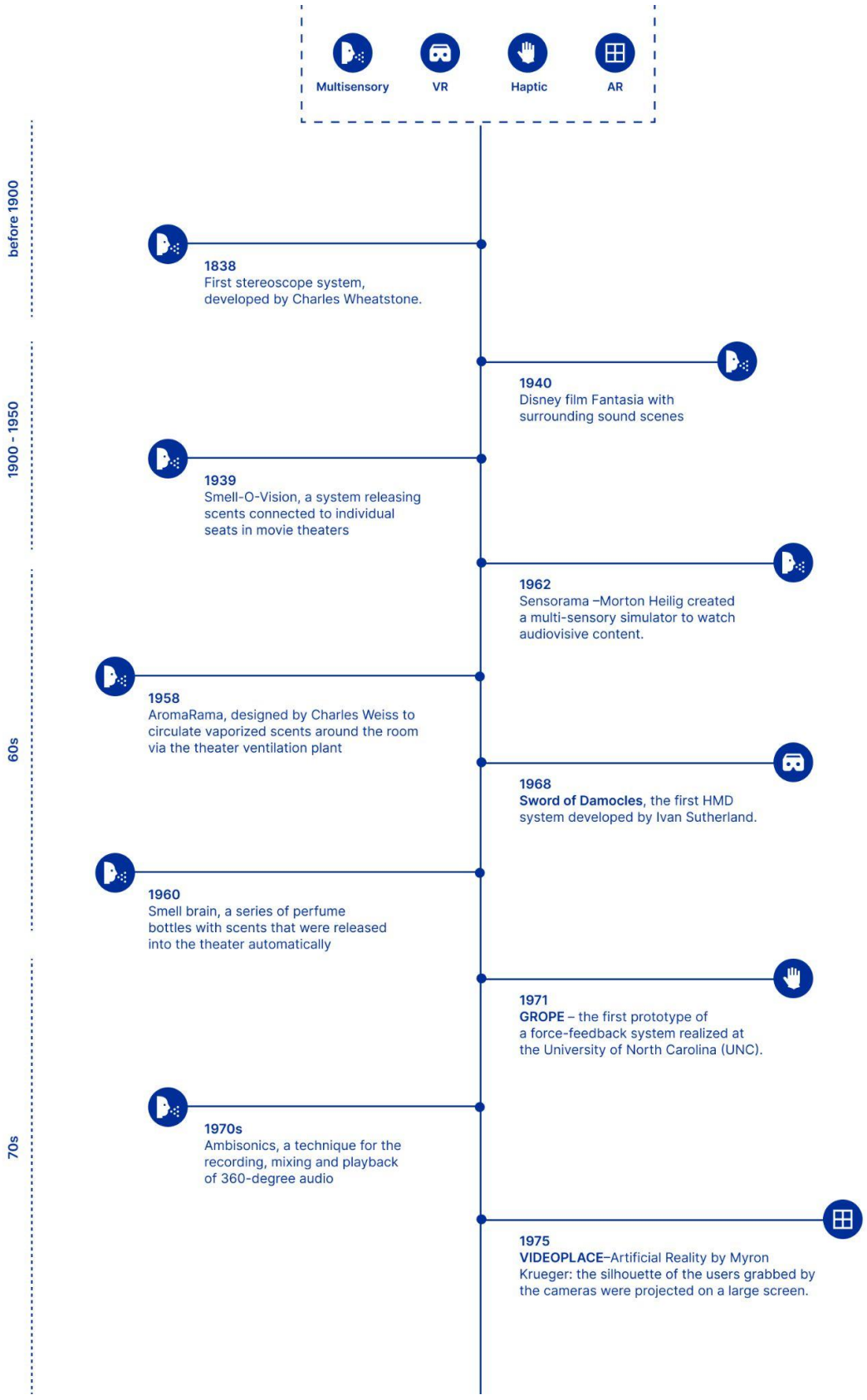
GROPE, a first force-feedback system was prototyped and tested. It represented an essential step in the field of haptic technology (Brooks et al., 1990), as well as for user interaction.

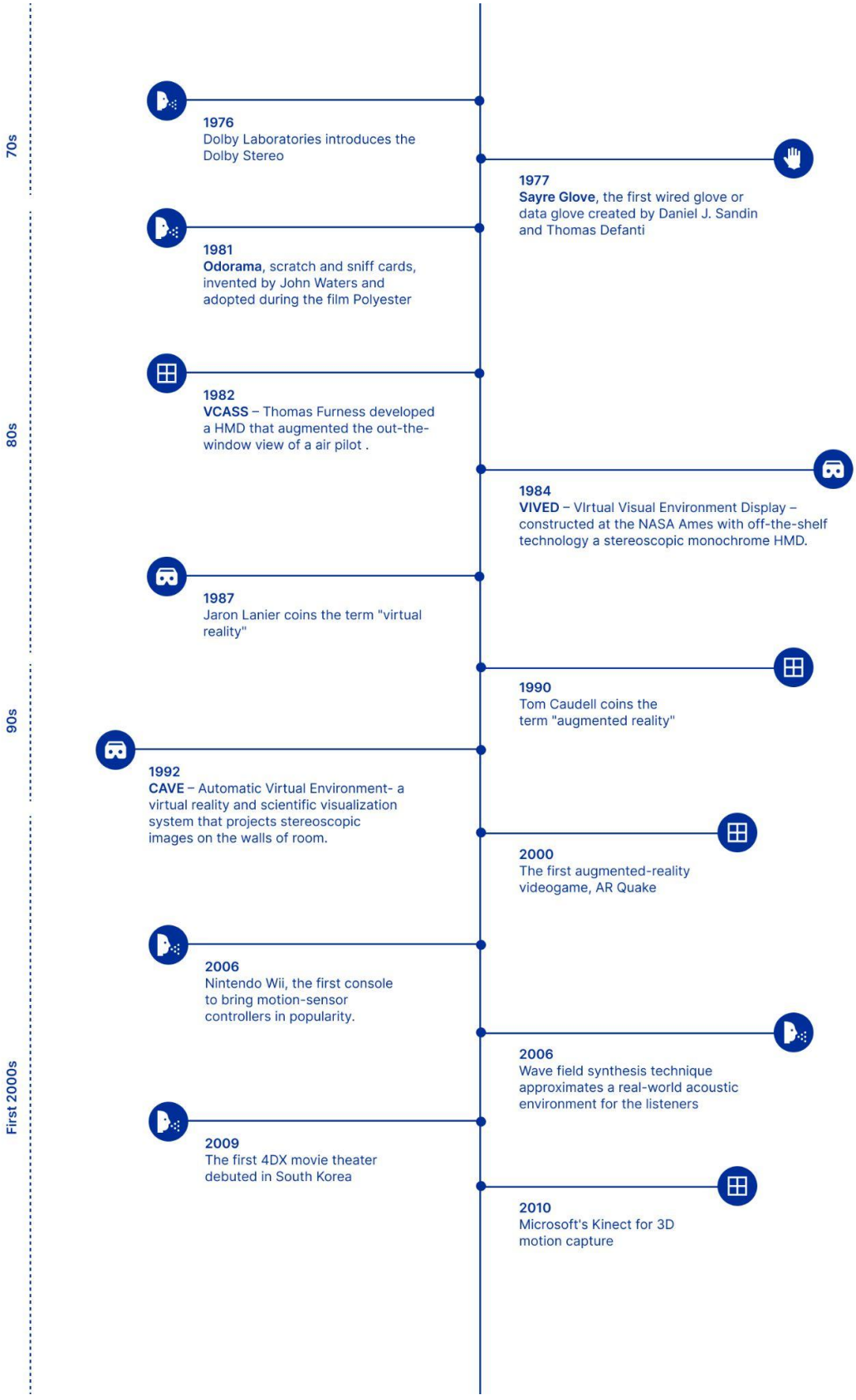
In relation to haptic technology, at the end of the seventies, 1977, Daniel J. Sandin and Thomas Defanti at the Electronic Visualization Laboratory created the *Sayre Glove*, the first wired glove or data glove. The system could monitor hand movements, providing an effective method for multidimensional control, such as mimicking a set of sliders (*Daniel J. Sandlin Invents the Sayre Glove: History of Information*, n.d.)

Another step into navigation/interaction tools development occurred from 1985 to 1988 when the VPL company manufactured the popular *DataGlove*, a glove that used hands as input for other devices (Vradmin, 2017). A popular reinterpretation of the Data Glove on the consumer market was the *Nintendo Power Glove*. Additional navigation and interaction tools not related to the physical size of hands were Magellan or various six degrees of freedom joysticks.

Interactive surfaces

The advent of interactive surfaces began with *VideoPlace*, created by Myron Krueger in 1975. It was defined as "a conceptual environment, with no existence." In this system, the silhouettes of the users grabbed by the cameras were projected on a large screen. The participants could interact with one another thanks to image processing techniques that determined their positions in a 2D screen space (*The Digital Age / Myron Krueger*, n.d.). This first strong interaction led users to feel immersed in this sort of augmented reality scene. Nowadays projected walls (retro or front) and LCD displays on vertical or even horizontal surfaces can ensure good performances and reduce the need to operate in light-controlled conditions.


Multisensory
VR
Haptic
AR
before 1900
1900 - 1950
60s
70s
1838
First stereoscope system, developed by Charles Wheatstone.
1940
Disney film Fantasia with surrounding sound scenes
1939
Smell-O-Vision, a system releasing scents connected to individual seats in movie theaters
1962
Sensorama –Morton Heilig created a multi-sensory simulator to watch audiovisive content.
1958
AromaRama, designed by Charles Weiss to circulate vaporized scents around the room via the theater ventilation plant
1968
Sword of Damocles, the first HMD system developed by Ivan Sutherland.
1960
Smell brain, a series of perfume bottles with scents that were released into the theater automatically
1971
GROPE – the first prototype of a force-feedback system realized at the University of North Carolina (UNC).
1970s
Ambisonics, a technique for the recording, mixing and playback of 360-degree audio
1975
VIDEOPLACE–Artificial Reality by Myron Krueger: the silhouette of the users grabbed by the cameras were projected on a large screen.


70s
80s
90s
First 2000s
1976
Dolby Laboratories introduces the Dolby Stereo
1977
Sayre Glove, the first wired glove or data glove created by Daniel J. Sandin and Thomas Defanti
1981
Odorama, scratch and sniff cards, invented by John Waters and adopted during the film Polyester
1982
VCASS – Thomas Furness developed a HMD that augmented the out-the-window view of a air pilot .
1984
VIVED – VIrtual Visual Environment Display – constructed at the NASA Ames with off-the-shelf technology a stereoscopic monochrome HMD.
1987
Jaron Lanier coins the term "virtual reality"
1990
Tom Caudell coins the term "augmented reality"
1992
CAVE – Automatic Virtual Environment- a virtual reality and scientific visualization system that projects stereoscopic images on the walls of room.
2000
The first augmented-reality videogame, AR Quake
2006
Nintendo Wii, the first console to bring motion-sensor controllers in popularity.
2006
Wave field synthesis technique approximates a real-world acoustic environment for the listeners
2009
The first 4DX movie theater debuted in South Korea
2010
Microsoft's Kinect for 3D motion capture

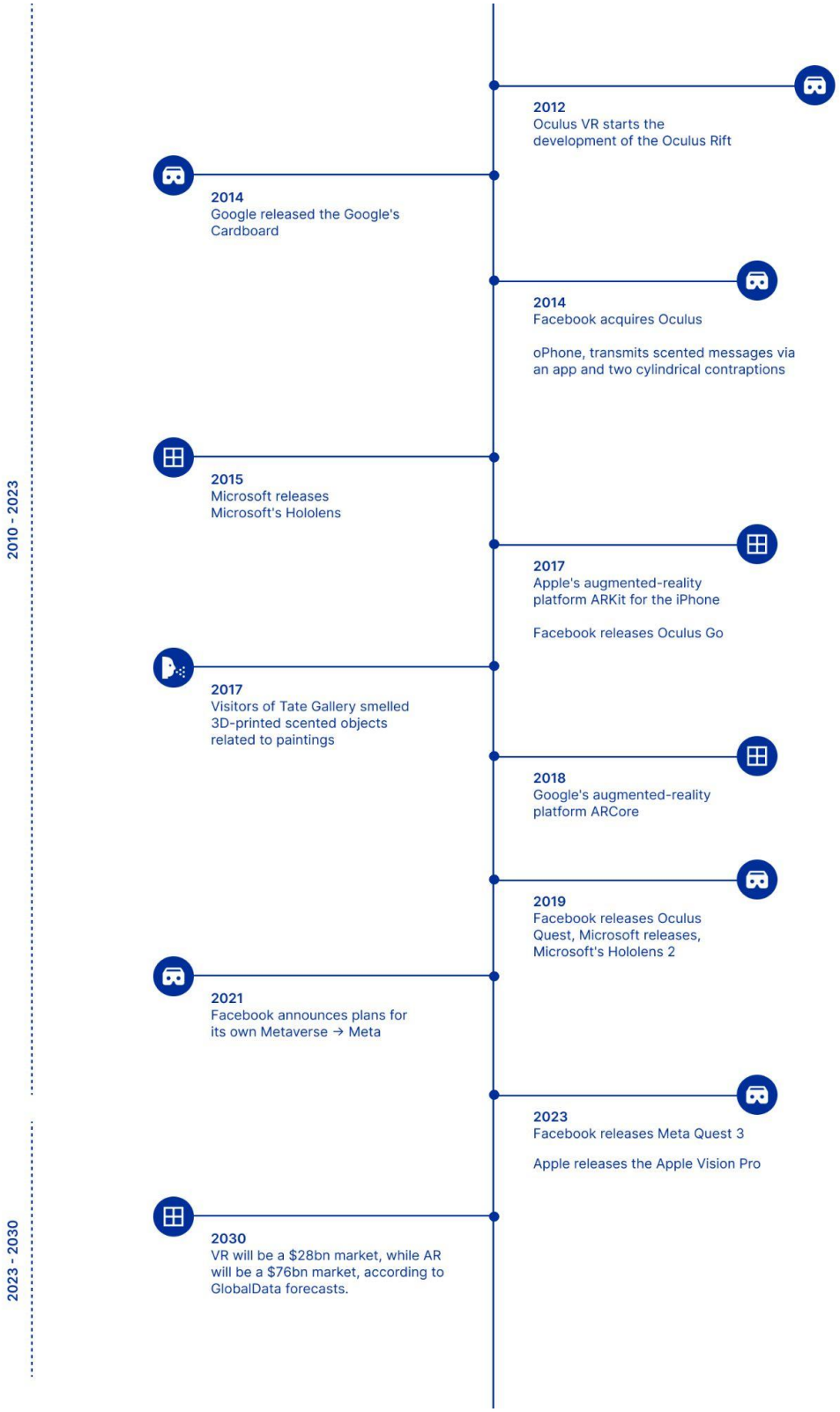


Fig. 3: History timeline of the application of immersive technologies from 1838 to present.

3 Case studies collection and analysis

3.1 Introduction and Methodology

Focused on a theoretical level for the definition of the concept of immersion, the systematic literature review was expectedly insufficient to adequately address practical implications of immersive experiences. However, this kind of information is very useful for the research project, as expressed in the research objectives.

More precisely, elements like technologies and tools, users, interaction modalities, design process, and actors involved throughout the conceptualization, development, and realisation of immersive experiences proved challenging to map from the analysed scientific articles. To gain further insights on these aspects, the research team pursued an exploratory investigation based on a case studies analysis, the collection of which was carried out through the distribution of an online questionnaire among the European consortium partners.

Acknowledging the countless examples that could be gathered concerning immersive installations and experiences, the selection of the case studies leveraged the expertise of the partners participating in Artcast 4D. They were tasked to contribute with examples they deemed relevant for the research project, also to build a set that could be representative of the consortium's perspective in the research domain. The initial target was set at approximately 50 case studies as key performance indicators (KPIs). However, in the end, the final set included 57 case studies for a more comprehensive overview.

The collected case studies were eventually mapped against the dimensions of interest to infer relevant insights on the actors involved, the features of installations and experiences (like technology, tools, interaction modalities, etc.), and – possibly – those of the design processes for creating immersive experiences.

Furthermore, to understand their effectiveness in conveying immersive experiences, the *Keys of Immersion* emerging from the preliminary literature review were applied as characterising dimensions for an intercoder agreement evaluation performed by the research team conducting the investigation. As not all the case studies collected were suitable for the assessment, those with not sufficient information and in which technology did not play an active role for conveying a sense of immersion were excluded, bringing to a final set of 52 case studies. From this activity, a synthetic value including the perspectives of the five researchers could be extracted as a definition of the immersiveness of the case studies. Thus, they could be classified to identify the most relevant for further deepening.

3.2 Questionnaire structure

The case studies collection was carried out through an online questionnaire that was developed and shared with the project partners using Google Forms.

The results from the literature review along with a preliminary analysis of a few case studies identified by the researchers conducting this study informed the structure of the questionnaire. Indeed, these allowed the development of a series of multiple-choice questions to facilitate the description of the examples provided by ensuring homogeneity and granularity.

The questionnaire, reported in the Annex section of this report, was meant to create a set of relevant case studies of immersive experiences in different fields of application. The objectives of the investigation as well as the relevant information to address were introduced and properly explained to the colleagues contributing to the collection beforehand.

The questionnaire is articulated in six sections as portrayed in Figure 4.

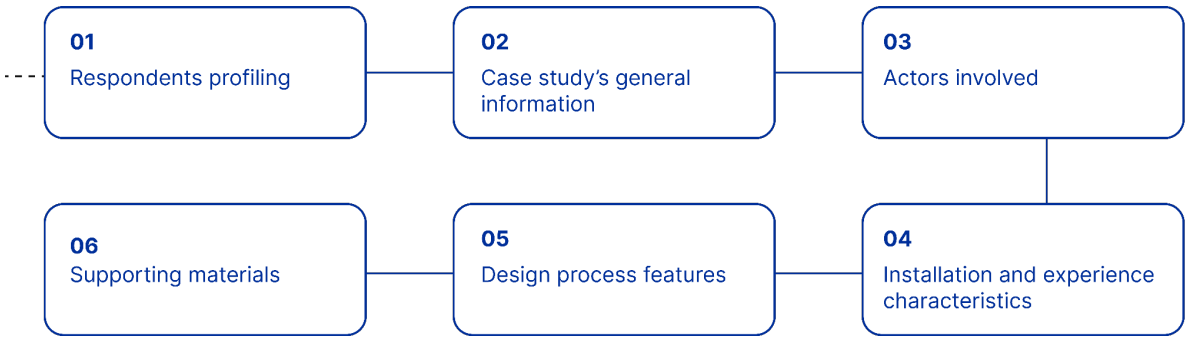


Fig. 4: Questionnaire structure depicting its six sections.

01. The first section presented questions regarding profiling information about the participant compiling the questionnaire (name and surname, affiliation, and email contact for possible follow-up).

02. In the second section of the questionnaire, participants were asked to provide general information about the selected case study. Namely, title, year, location, synthetic description, reason for providing the example introduced, and finally its objectives and fields of application by choosing among a list of proposed possibilities or suggesting new ones.

03. The third section focused on the depiction of the actors involved. The inquiry was firstly oriented toward the people or bodies commissioning the experience. Then, it opened the floor to further actors who might be involved focusing on their multidisciplinary background, their role in the immersive experience's design process,

their precise identification (if available), the possible need for technicians for the set-up of the experience/installation, and the characterisation of the users targeted.

04. The following section went into more specific details about the installation characterising the presented case study and the experience enhanced by it. More in detail, the questionnaire asked to choose the type of technology and technological tools adopted and to indicate the envisioned duration of the installation or exhibition before concentrating on the features defining the experience. In this regard, the attention focused on sensory stimulation, interaction modalities, the possibility of personalization, cooperation, storytelling, or gamification.

05. The fifth section of the questionnaire concerned the design process of the installation and the related experience. Starting from the testing phase of the case study, it aimed to understand if that was conducted in the lab or on the field. Subsequently, an open question also asked about the main phases of the design process, while a multiple-choice question investigated the software used in support, with the purpose of identifying whether open-source ones were adopted.

06. To conclude, the last section of the questionnaire was dedicated to the collection of additional materials concerning the case study, such as external links, videos, images and other useful documents for providing a deeper understanding.

3.3 Assessing the case studies according to the *Keys of Immersion*

After the depicted overview, which was based on the relevant elements collected through the questionnaire, a further step of analysis was necessary to gain a deeper understanding of the set of case studies in relation to the *Keys of Immersion* previously identified. This allowed to observe the alignment between the consortium partners and the researchers conducting the investigation in terms of experiences enabling a sense of immersion, and to select the most effective ones for a more thorough study (which will be described in the next chapter).

To determine how immersive each case study was perceived, the five researchers in charge of this WP of the Artcast 4D project carried out a crossed evaluation, seeking intercoder agreement (Creswell, 2014). Specifically, each of them, in the role of judge, had to assess all the case studies according to the *Keys of Immersion* emerging from the literature review, which were recognized as the essential features to define the immersive nature of an installation or experience. For this purpose, *engagement* and *isolation* were better specified and the final set included *presence, cognitive engagement, emotional engagement, sensory involvement, embodiment, isolation, social isolation*, but the latter was not considered for the overall evaluation as it is not mandatory requirement to achieve immersion and the sample was too skewed.

The evaluation articulated on a 1 to 5 scale (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, more importantly on video resources). To guarantee consistency in the assessment, the research team previously agreed on the definition of the extreme values for each *Key of Immersion* as described in the following.

- *Presence* reports 1 as *not feeling there* and 5 as *feeling there*.

- *Cognitive engagement* spans from *distracted* (1) to *focused* (5).

- *Emotional engagement* implies a very subjective evaluation in envisioning the possible perception of *boredom* (1) or *excitement* (5) while experiencing the case study.

- For *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. More precisely, 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.

- To conclude, the research group identifies *isolation* as the sensation that users feel with respect to the concrete world, with no superimposed meanings or layers of reality. Therefore, 1 stands for *not isolated* and 5 for *completely isolated*, thus immersed in the dimension conveyed by the case study.

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* (except for *social isolation*) was calculated. Finally, to get a comprehensive overview and compare the collected case studies, they were organised into quartiles based on their synthetic immersion values (Fig. 5).

	Case study	Z score average
4th quartile	OVR Dark	1,63
	Anima Mundi	1,07
	Museo di Monte San Michele	0,84
	Dataspace - Deep Space 8K	0,84
	Borderless	0,75
	VR Workshop in Polimi	0,67
	Nefertari Tumb	0,64
	The Dreamachine	0,62
	Rain Room	0,61
	Mona Lisa VR	0,60
	Collio XR	0,53
	Nuii, VR adventure	0,53
	Dreams of Dali	0,49
3rd quartile	Exstasis	0,43
	OSNI 2 Cartier	0,39
	Mekorot FieldBit	0,39
	Giostra del Saracino - CarraroLAB	0,35
	NAO	0,30
	Goliath	0,29
	Van Gogh Exhibition	0,29
	Spaces in Between	0,26
	Earth	0,25
	Illuminated Art Attisholz	0,24
	I AM (VR)	0,19
	Infinity Room	0,17
	Kremer Museum	0,11

		Z score average
2nd quartile	Frameless	0,08
	El Roque de los Muchachos Visitor Centre	0,06
	Room to Breathe	0,05
	CWRU Hololens	0,03
	Oculus Nohlab	0,02
	See me through you	0,003
	MARSS (MusAB from science to society)	-0,14
	Rome's Invisible City VR	-0,18
	Immersive Space Series - OOT	-0,29
	David Hockney - Lightroom - Bigger & Closer	-0,32
	MoMa virtual tour	-0,47
	MANZONI 23 – Perpetual Immersive Experience	-0,52
	Olafur Eliasson: Trembling horizons	-0,54
1st quartile	MUSME - Museo della Medicina	-0,56
	Falls from the Sky, Aerosplane, Flutter	-0,57
	Galileo all'Inferno (spectator pov)	-0,59
	Skin awareness (spectator pov)	-0,63
	The Hidden Music of Leonardo (spectator pov)	-0,73
	The Anatomy Lesson of Dr. Nicolaes Tulp	-0,74
	Primary Intimacy of being	-0,83
	Palacio de la Aljafería	-0,98
	Ruta Maestrat	-1,08
	Ariadne's Fibres	-1,09
	The Dynamic version of Chinese ancient painting	-1,13
	The Eye of Mars	-1,16
	Gymkana Camp de Morvedre	-1,16

Fig. 5: Results of the intercoder agreement activity performed by the research team. The final case studies selected are organised into quartiles according to the researchers' evaluations: the blue one is the fourth quartile, the most interesting for the investigation, while the red one is the first one, including the case studies with a lower immersion score. The table presents the name of the case studies (first column) and the average value of the obtained z-scores to synthesize the immersiveness of each case study (second column).

The most significant examples of immersive experiences emerged from the fourth quartile (>75%), and the 13 case studies included were the preferable ones for a deeper analysis through semi-structured interviews.

3.4 Case studies distribution and analysis

The data collected with the questionnaire have been organised and analysed by using Google Sheets, in order to understand the case studies distribution. Based on

Case study name	Year	Location
Falls from the Sky, Aerosplane, Flutter	1993	Villa Panza, Varese, Italy
Nefertari Tumb	1994	Rome, Infobyte SpA, Italy
Magnetic field explorer	1994	Politecnico di Milano, Milan, Italy
Galileo all'Inferno	2005	Milan, Italy
CELL - Centre for Experiential Learning	2009	Padova, QBGROUP, Italy
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	Museum of art and craft, Paris, France
Rain Room	2012	Barbican, London MoMA, NY Yuz Museum, Shanghai LACMA, LA Sharjah Art Foundation, UAE Jackalope Art Pavilion, Melbourne Museum of Contemporary Art, Busan The Maxine and Stuart Frankel Foundation for Art, MI
Mekorot FieldBit	2014	Mekorot company, Israel
MUSME - Museo della Medicina	2015	Padova, Italy
See me through you	2015	Cité des sciences et de l'industrie, Paris, France
Infinity Room	2015	Istanbul Biennal- Zorlu performing art center, Istanbul, Turkey
Immersive Space Series - OOT	2016	San Francisco Bay, Youtbe and Google Offices
Oculus Nohlab	2016	Tophane-i Amire, Istanbul, Turkey
Dreams of Dalì	2016	Dali Museum, St Petersburg, USA
CWRU AR headset	2016	CAse Western Reserv Unviersity, Cleveland, USA
Museo di Monte San Michele	2017	Italy, Gorizia, Sagrado
7D hologram technology	2017	Several location world-wide
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, Italy
Van Gogh Exhibition	2018	Moving exhibit
Ariadne's Fibres	2018	Paris, Forum des images, France
Skin awareness	2018	London, UK
Nuii, VR adventure	2019	Spain
The Hidden Music of Leonardo	2019	Louvre, Paris, France
Exstasis	2019	Santa Caterina d'Alessandria church, Palermo, Italy
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, Netherlands
Illuminated Art Attisholz	2020	Solothurn, Attisholz Areal, Switzerland
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	Orto Botanico, Palermo, Italy
Goliath	2021	Online
MMANZONI 23 – Perpetual Immersive Experience	2021	Via Manzoni 23, Milan, 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	Castello di Rivoli, Rivoli, Turin
I AM (VR)	2022	Triennale Milano, Milan, Italy
The Dreamachine	2022	London, UK
Deep Space 8K	2022	Ars Electronica, Linz, Austria
Yayoi Kusama - Infinity Mirror Rooms	2022	Hirshhorn Museum and Sculpture Garden, Washington, DC
Marco Denni	2022	Tokyo
OSNI 2 Cartier	2022	Rue Robert Esnault-Pelterie, Paris, France
Room to Breathe	2022	Outernet space, London, UK
Chaplin's World	2023	Corsier-sur-Vevey, Switzerland
NAO	2023	Alicante, Valencian Community, Spain
David Hockney - Lightroom - Bigger & Closer	2023	Lightroom space, London, UK
Frameless	2023	London, UK
Spaces in Between	2023	Outernet space, London, UK

Fig. 6: All collected case studies schematization reporting the name, year and location.

the questionnaire structure, the case studies have been clustered to map them against the items relevant to the research. This allowed direct observation of the case studies distribution, as portrayed in the following (figures 8 to 14).

3.4.1 Case study's general information

The first part of the questionnaire allowed to collect of general information about the cases, in order to create a general frame and to underline the fields of application, to which the experiences/installations belong.

Case study general frame

The initial information obtained by completing the questionnaire relates to generic data relating to the case studies reported. These data relate to the name of the experience/installation selected as a case study, the year and the location where the experience/installation took place. As can be seen from Fig. 6, most of the cases collected date back to 2022, with a presence of 12 cases, while a large number of cases are from the period between 2021 and 2019, presenting 6 cases per year. There are only three selected cases linked to experiences or installations prior to 2000s, two of which date back to 1994 and one to 1993.

Fields of application

Each case study has been mapped to its corresponding field of application, along with its objectives and aims. The research is focused on art and cultural field applications, as is evident from the distribution of the fields of application of the collected case studies from the consortium, reported in Fig. 7. Cultural heritage and art are the largest cluster in this distribution, followed by entertainment, which refers to experiences and installations that aim to create an entertaining experience for visitors. Education has also been frequently reported in the distribution.

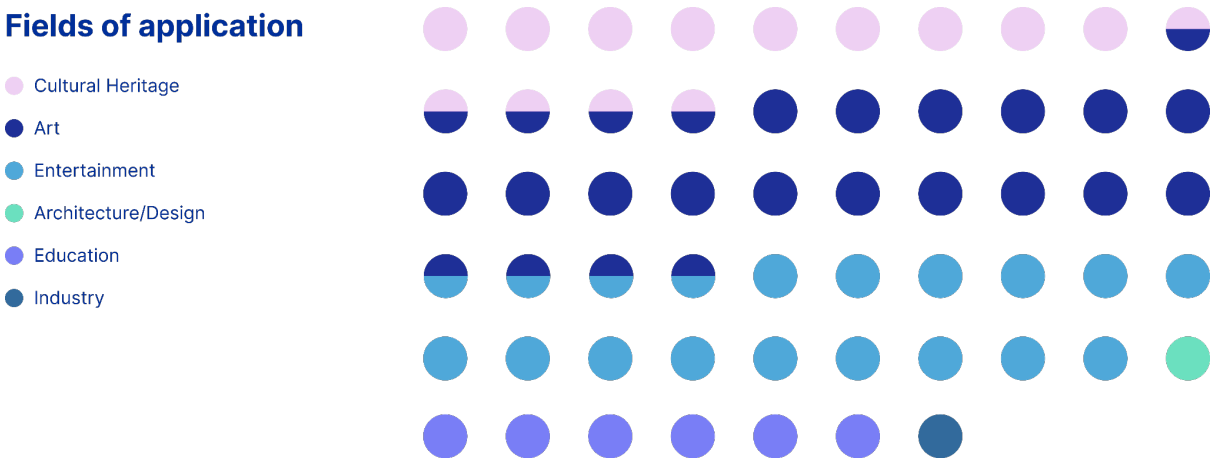


Fig. 7: Mapping the case studies in reference to the fields of application item.

3.4.2 Actors involved

The actors involved have emerged from the analysis of the dataset just at a superficial level, delineating their roles in a generalised manner. It has been slightly difficult to identify precise information about the actors, and a subsequent further analysis has been considered mandatory to deepen some aspects. Regrettably, it has not also been possible to identify the moments in which the actors manifest within the process, as well as the interplays amongst them, which remain elusive. Unfortunately, these specific aspects are not inferable from the experience or installation itself, instead, they necessitate elucidation solely through a direct discourse with one or more adept practitioners implicated in the formulation of the resolution. In spite of this, it has been possible to highlight the commission, the multidisciplinarity of the actors background and their roles, the presence of technicians for the set-up of the installations, and their tasks. More actors can be related to a single case study.

Commission

The investigation of the case studies was undertaken with the objective of comprehending the nature and scope of the engagements associated with the experiences and installations. Notably, the primary entities assuming the role of commissioners are cultural institutions and research centres, occasionally collaborating as stakeholders in the commissioning process. Within the corpus of case studies, a diverse array emerges, wherein numerous instances showcase financial backing provided by private companies, studios and offices, and private investors. These entities frequently assume creative responsibilities encompassing the design, development, and dissemination of the experiences themselves. State organizations are not so present in the collected case studies commission (Fig. 8).

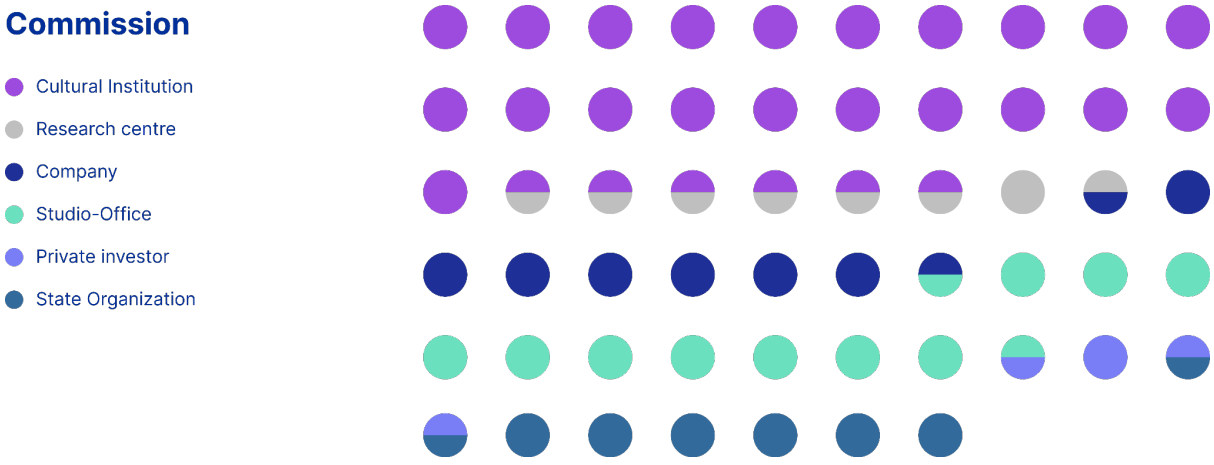


Fig. 8: Mapping the case studies in reference to the commission stakeholders.

Actors' background

One of the aspects examined through the questionnaire pertained to the multidisciplinarity of the actors engaged in the experience design process, one of the core topics of this study. The collected data elucidate that in the wide majority of instances, the actors involved have multidisciplinary backgrounds (see Figure 9), thus highlighting that multiple distinct roles and knowledge domains are required for the crafting of an immersive experience.

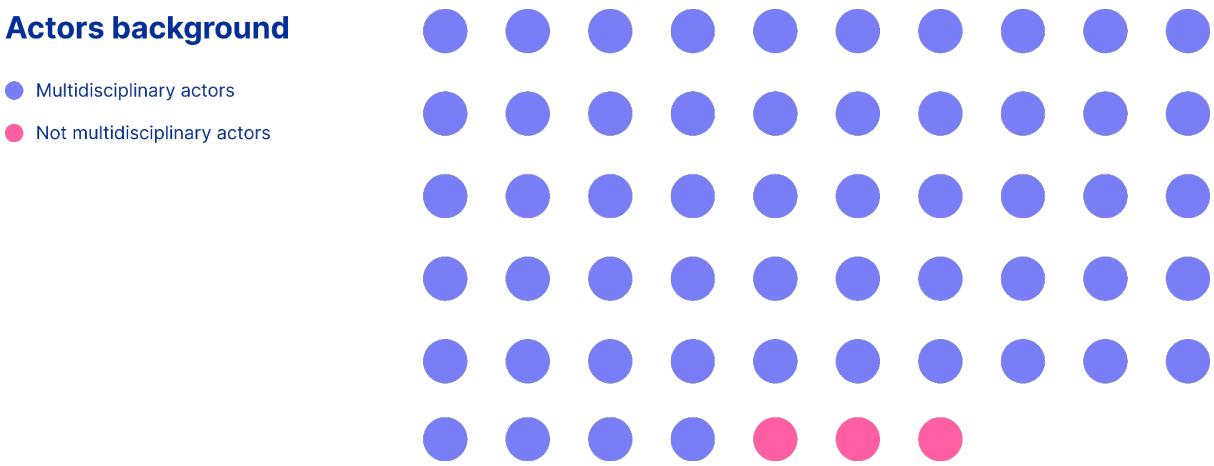


Fig. 9: Mapping the case studies in reference to the multidisciplinarity of the actors background.

Actors' role

The role of the actors involved in creating the selected case studies was also investigated through the questionnaire. However, as mentioned, these data have been slightly difficult to collect and have often been hypothesised and deduced from the information available online.

As can be noticed in Fig. 10, the main actors indicated are designers and developers, as could be expected from the strong technological connotation of the selected cases. Secondly, we find the figure of the artists, and only later figures like the museum curators and the engineers. For the purpose of the analysis, all roles have been catalogued to report the number of times they have been indicated as belonging to a case study. Some roles have been merged, predicting the appearance of the typology only once: for example 3D artists, which appeared only once in the sample, was encompassed by the broader category of the artists, as well digitising programmers, that appeared only once, was merged with the developers category, and philosophers with humanistic subject experts. Given this work of synthesis, in the designers category, referred to as the most recurring, are included figures such as

graphic designers, interaction designers, sound designers, who deal with different aspects within the project.

Other roles such as the animators, educators, producers present 2 recurrences, while roles that appeared only once were listed in the *Other* category.

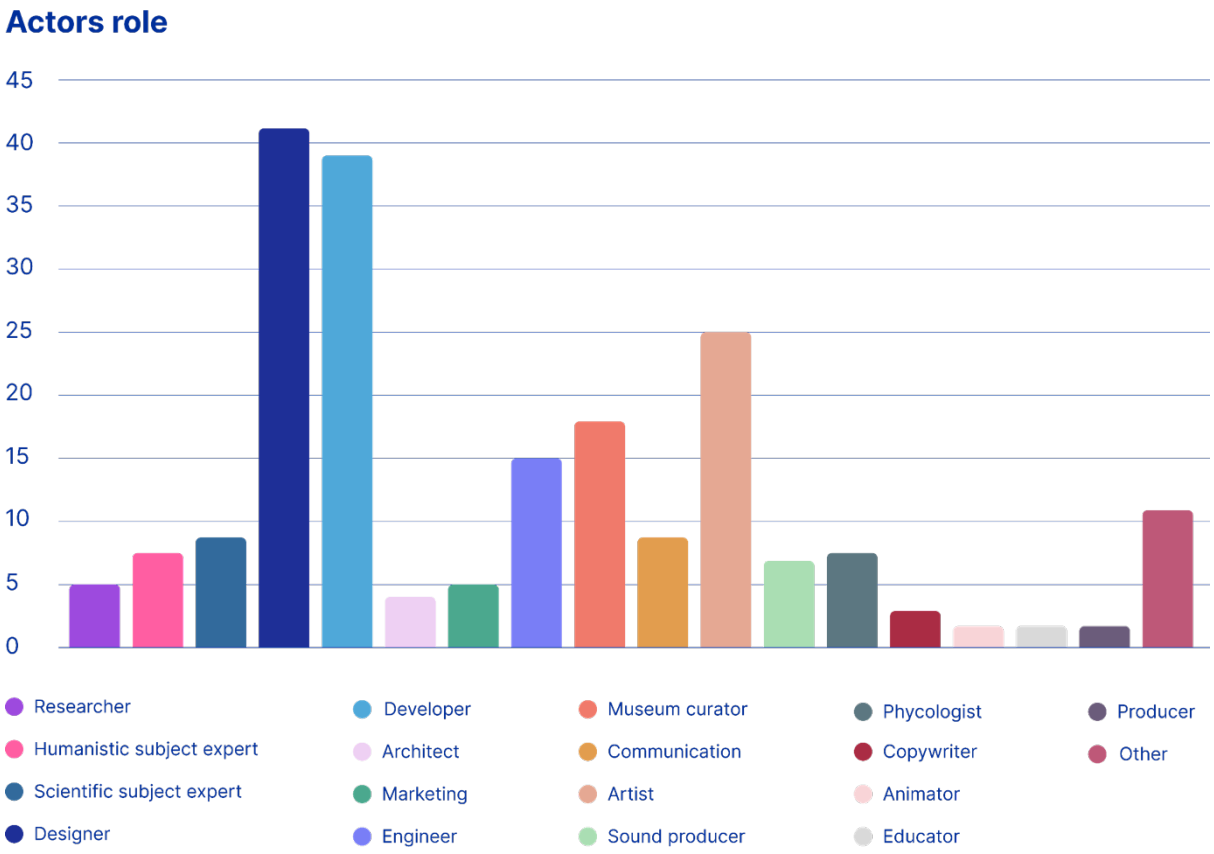


Fig. 10: Mapping the case studies in reference to the role of the actors involved.

The questionnaire also sought to identify the specific company/studio related to the actors, mapping them at a general level. This aspect has been difficult to return with the analysis as the data collected does not provide a uniform mapping of all the actors to highlight the institution of belonging. As there is no precise correspondence between the answers from the company/studio and the actors, and since the question was only partially answered, no relevant information could be gathered.

Installation Technicians

The case studies have also been mapped in reference to the presence of technicians involved in the setup of the installation.

It has been chosen to identify the presence – or not – of these actors since they often take over only in the final stages of the process and often it is lost track of, but they are fundamental to ensure the correct functioning of the technological set-up. As shown in Fig. 11, the sample of cases analysed showed that in 39 out of 57 cases, a technical actor was involved in the installation set-up.

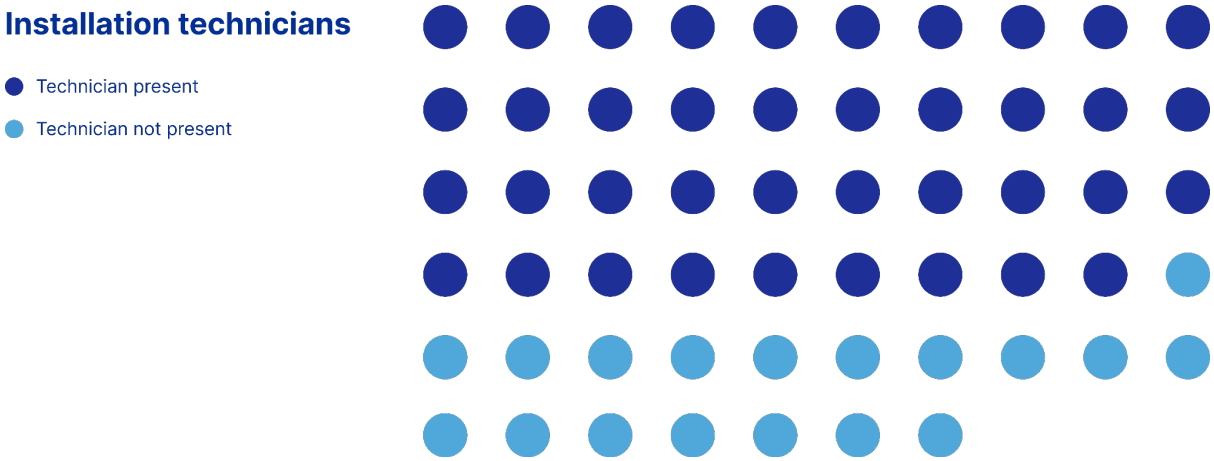


Fig. 11: Mapping the case studies in reference to the presence of technicians involved in the setup of the installation.

Technicians' task

The technical tasks that technicians need to address in relation to the type of set-up have also been mapped. Figure 12 reports a graphical representation. This reveals a conspicuous trend indicating, regrettably, that in numerous cases, a comprehensive analysis of the specific tasks was unattainable due to data limitations. This is manifest in the prominence of the item *Not specified*, which shows the highest frequency of occurrence of about 20 instances. Among other items encompassing various technical tasks, prominence is given to *Audio system* installations, along with the inclusive category of *Overall set-up*. The latter pertains to instances in which technicians assumed multifarious responsibilities, including various operational facets of the setup and not presenting a defined role. In these cases, the technicians have different skills. However, the available data make it difficult to reconstruct their precise functions. Furthermore, a high recurrence of 9 installations is attributed to the *Projection system*, whereas installations such as *LED wall*, *Supply chain*, *Camera 360*, *Architecture system*, and *Art installation* occupy more peripheral positions, each appearing just once.

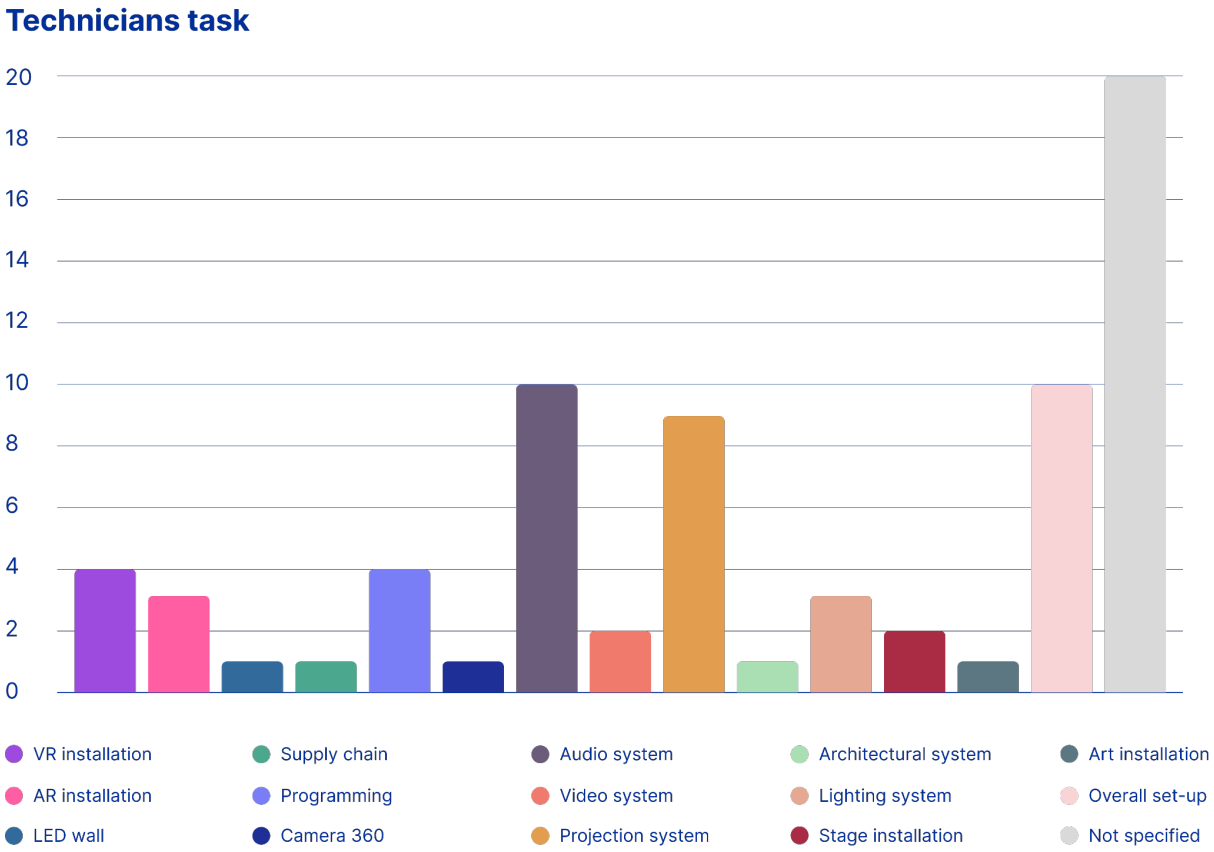


Fig. 12: Mapping the case studies in reference to the task of technicians in relation to the installation typology.

3.4.3 Installation and experience characteristics

The fourth part of the questionnaire aimed at deepening the knowledge about the immersive experience or installation selection. Here, some specifications regarding the technology and tools adopted, and the experience characteristics are examined in more detail.

Technology and tools

After the analysis of collected data, it was decided to map the *Technology and tools* used during the experience, to better understand the immersiveness in relation to the technologies and tools adopted. In particular, the AR and VR immersive technologies have been clustered, alongside different enabling tools, such as headsets, projection and mobile, to obtain six different specifications: *AR headset* (e.g.: Microsoft Hololens), *AR projection* (projections on a specific physical surface, augmenting the tangible element with artificial content), *AR mobile* (use of mobile devices to displace artificial content able to augment a tangible element through the point of view of the device itself), *VR headset* (e.g.: Meta Quest 2), *VR projection* (projections surrounding the

user; the tangible environment is totally substituted by the artificial one), *VR mobile* (use of mobile devices to displace artificial content surrounding the user into the overall environment visible through the device itself). In addition, four other technologies have been mapped along the collected data.

The most prominent technology in the distribution is clearly VR, and specifically the *VR headset* (as shown in Fig. 13), reflecting the recent attention it has gained both in relation to the definition of immersion and the concrete development and application of this technology. Considering the AR cluster, the main tools used are mobile devices, recurring in 7 cases. The *Interactive surfaces*, which include LCD, front- and retro-projected walls and floors displaying content the users can interact with, are reported in 5 case studies, indicating probably the presence of body tracking and body interactions from the users' side. Considering the sample, one of the cases has been classified as *No technology*, referring to an experience that has been indicated as immersive but with no use of technology inside it.

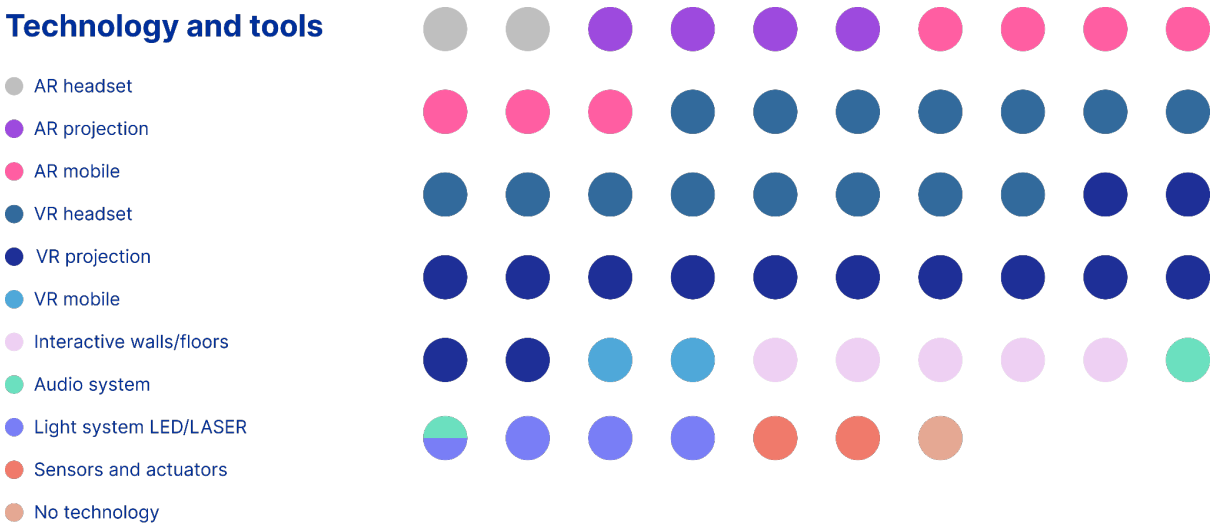


Fig. 13: Mapping of the case studies in reference to the technology and tools item.

Duration of the experience

Further data have been mapped to investigate the duration of the experience, distinguishing between permanent and temporary (Fig. 14). The experiences mapped as temporary entail a date of beginning and end, while the permanent ones are extended until today. Considering this aspect, the sample examined is divided exactly in half, presenting 26 temporary experiences and 26 permanent experiences, while in 5 cases, it was not possible to trace the duration of the experience, and the case study was referred to as *Not specified*.

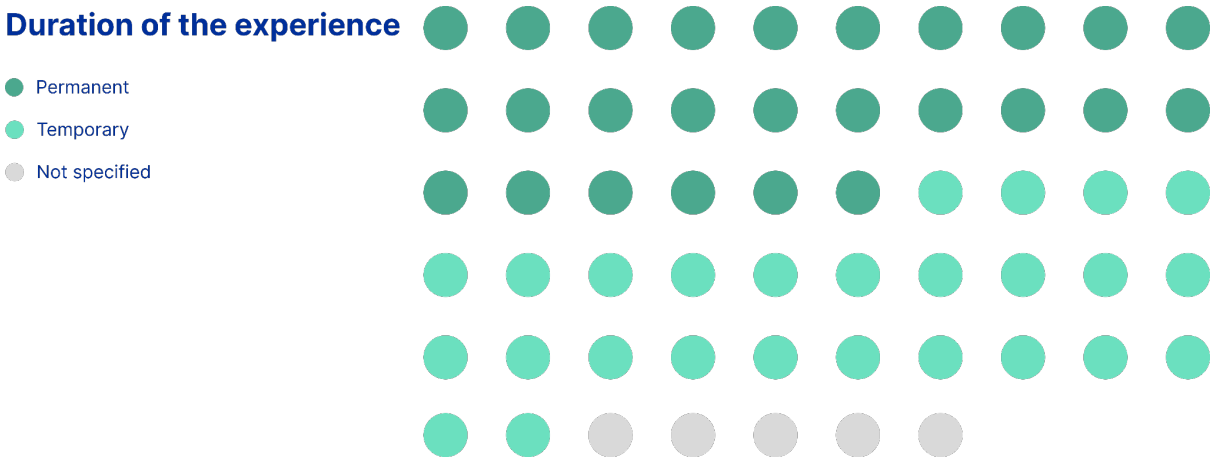


Fig. 14: Mapping of the case studies in reference to the duration of the experience.

Duration of temporary experience

The 26 temporary experiences mapped out have been further analysed focusing on their duration. Among these, 8 do not have a constant duration since often they indicate itinerant experiences, characterised by variations in the type of event and location, and of which it has been difficult to reconstruct an exact timing classification. These experiences have fallen under the category *Not specified* (see Fig. 15). Other experiences have been mapped to identify time ranges. 6 experiences lasted less than 10 days, including both one-hour experiences and experiences organised for a few days. On the other hand, 8 experiences lasted between one and six months, while 4 experiences lasted between six months and one year.

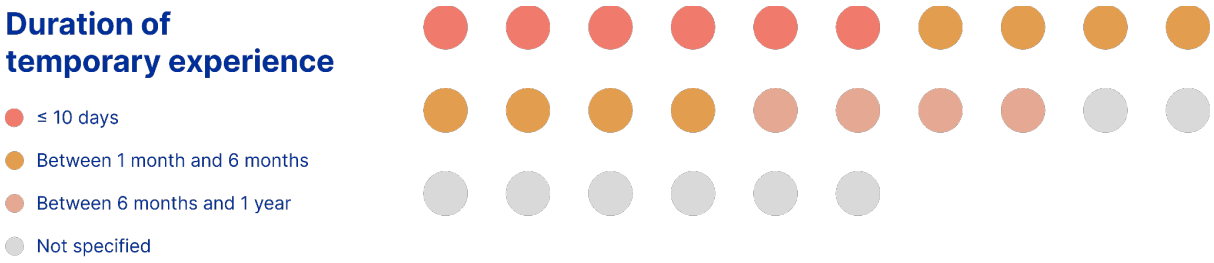


Fig. 15: Mapping of the temporary experiences in reference to their duration.

Sensory stimulation

The mapping activity, in this context, focuses on the quantification of sensory modalities engaged during the course of experiences. Specifically, immersive installations and experiences predominantly entail the activation of two senses, as evidenced by the illustrative depiction in Figure 16. The preponderance of case studies in this domain focuses on the sensory faculties of vision and audition as primary targets of human perception. However, a subset of three-sensory case studies

documents the inclusion of tactile elements (via haptic devices or textural physical components) or olfactory stimuli (involving the emission of scents and perfumes). Furthermore, instances involving only one sensory modality indicate scenarios where sight or hearing assume the role of unique sensory stimulation.

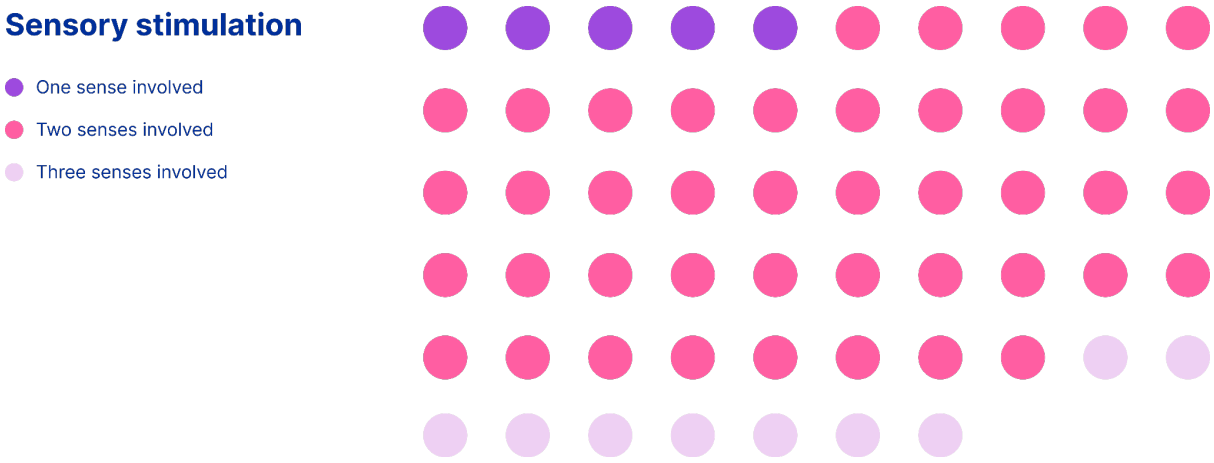


Fig. 16: Mapping of the case studies in reference to the sensorial involvement item.

Interaction modalities

Reporting the distribution of the case studies concerning the interaction modalities shown in Fig. 17, the research group took into account the degree of freedom that users had in their movements, ranging from a *Stationary user* to the possibility to *Move in tangible space* or to *Move in virtual space*. While there is a very large group of case studies that do not require users to move (16 cases), the majority of the experiences report the movement of the user in the space (23 cases). In addition, *Users interact with physical/digital objects* within the experiences in 12 case studies. It is also interesting to notice that only one of the collected cases requires the user to actively collaborate with the others.

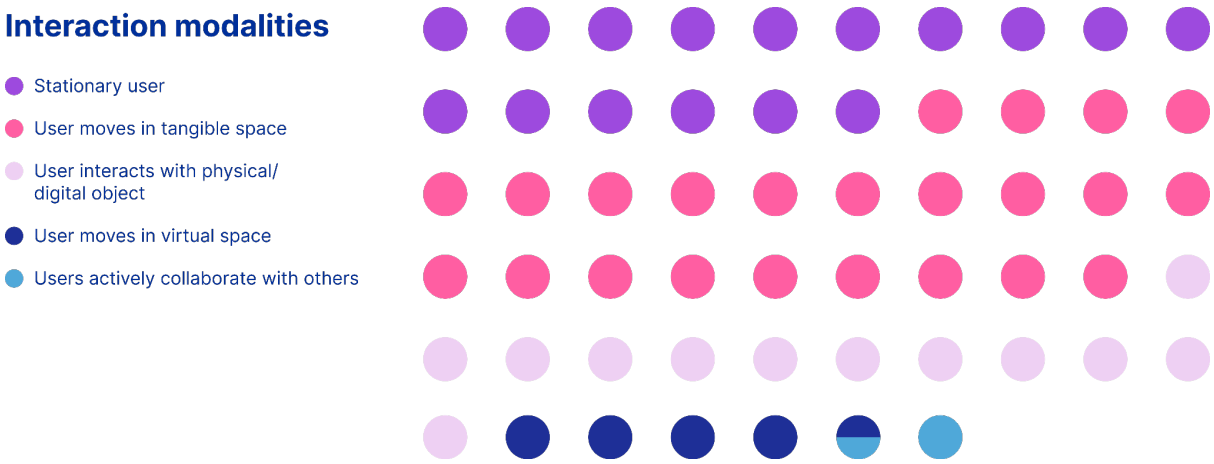


Fig. 17: Mapping of the case studies in reference to the interaction modalities item.

Experience characteristics

The questionnaire results revealed several characteristics of interactive experiences (Fig. 18). These included the presence of *Narrative elements* or *Playful elements* within the experience, as well as the fact that the experience has been *Personalized to individual user*. Not all of the case studies reported these characteristics (approximately half of them did) falling in the *No distinctive elements identified*. Of those, many relied on the cluster of narrative elements within the experience (17 cases). It is curious to observe the limited number of experiences that are personalized to individual users, related to 2 items.

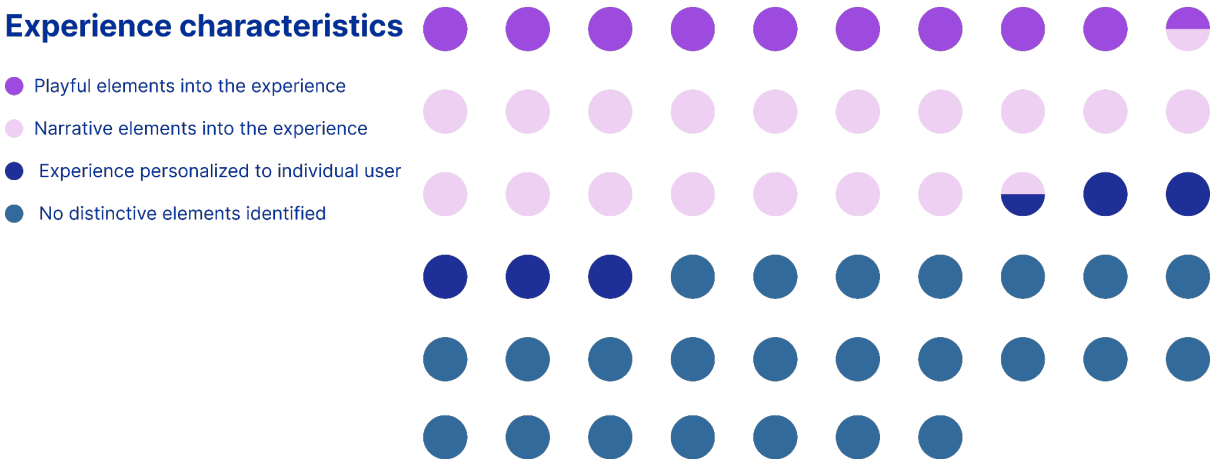


Fig. 18: Mapping of the case studies in reference to the experience characteristics.

Experience content

To better deepen the characteristics of the experience, the research team considered it valuable to map the data by highlighting the content of the experience, and the digital resources that led to its representation (Fig. 19). This has allowed to make insightful considerations on some of the trendsetting features in creating immersive experiences.

The categorization of the case studies in this context is based on the nature of the content showcased within them. Evidently, a substantial portion of the case studies predominantly features *Animated content*, present in 24 cases, while others also incorporate the *Reproduction of tangible elements* (e.g., 360 videos), or *Static content*. Case studies employing technological components such as *Light/Laser pattern* and *Audio experience* are less present in the sample. Furthermore, 3 instances are categorised as presenting tangible content.

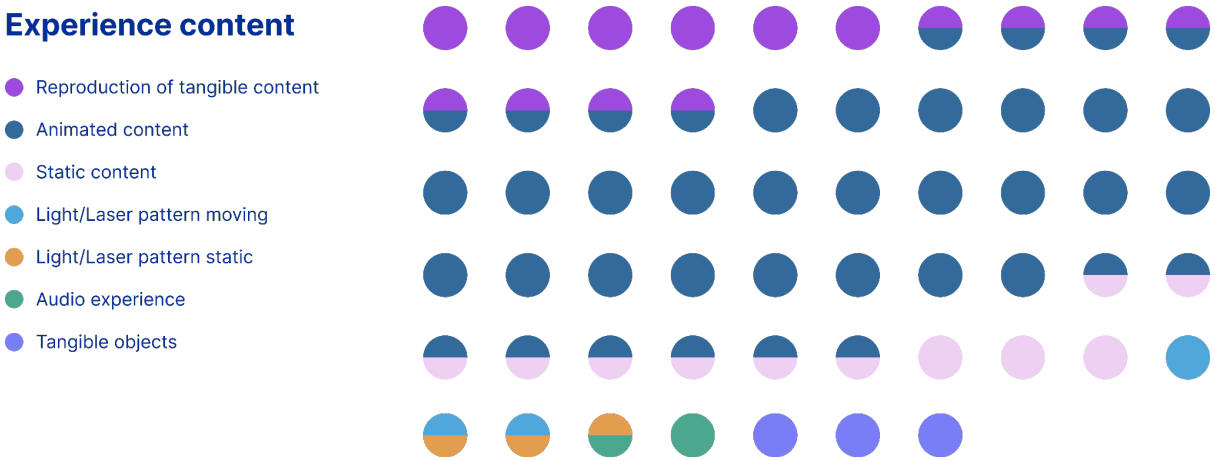


Fig. 19: Mapping of the case studies in refer to the experience content.

3.4.4 Design process features

In the fifth part of the questionnaire, some characteristics of the design process are collected. These data have been difficult to map precisely, and some aspects related, for instance related to the process phases, needed further investigation.

Context of the testing

The context in which the case studies were tested (Fig. 20) aimed at identifying whether the testing was conducted on the field or in the Laboratory (Lab), or in both conditions. The sample analysed showed that most of the cases were field tested with 45 cases, while only one case was tested under both conditions.

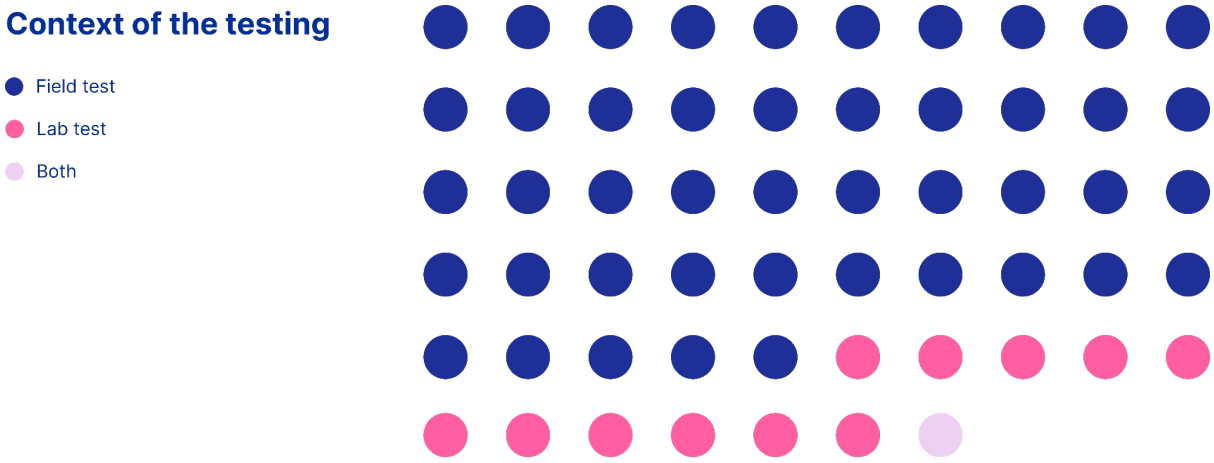


Fig. 20: Mapping of the case studies in reference to the context of the testing.

Design process

The design process adopted for the creation of experiences has also been mapped but the gathered information failed to yield valuable insights. Indeed, the collected data presented a lack of meaningful answers. It can be observed that often the question has been misinterpreted by participants, leading to the most various answers. Additionally, the design process has not been indicated, nor has a new process been described because they were unknown. Therefore indications about the linear or iterative nature of the process, as well as a specification of the design phases could not be found in the majority of cases. Just a very limited number presented them. Nonetheless, the interpretation of these phases on the basis of their names has been considered difficult and not objectively accurate to gain a meaningful outcome.

Adopted software

Considering the experience characteristics previously reported, it could often be possible to infer the typology of some of the software adopted. However, from the collected answers this kind of information was not always explicitly available or it was only partial. In addition, some of the indicated software did not match the actors involved or did not entail all the experience characteristics, not reporting the complexity of the immersive experience. In fact, it is reasonably expectable that a single case study includes multiple software that can be declined in many ways. But this aspect did not emerge from the respondents' answers, raising doubts about the accuracy and completeness of the available information.

From these considerations, portraying a software distribution adopting the collected data and deriving insights was considered unsuitable and misleading by the research team. This kind of information is expected to derive from a more narrow and detailed investigation with some of the actors actually involved.

3.4.5 Mapping the cases in relation to the *Keys of Immersion*

Due to the non representativeness of the sample of case studies, no generalizable considerations can be inferred. However, interesting observations can be reported based on the evaluations they received by the researchers in relation to the six *Keys of Immersion* identified (*presence, cognitive engagement, emotional engagement, sensory involvement, embodiment, isolation*).

Considering their performance in the overall immersion level, one can note that the examples in the first quartile (i.e., with the lowest scores) have in common an apparent layer of distance between the user and the experience itself. Some in the form of a smartphone guiding the experience and drawing attention to itself more than to the environment to be promoted (e.g., the applications to enhance Camp de Morvedre, Maestrat, or the Aljafería Palace); some with digital surfaces responding to people movements but not directly engaging them into a meaningful experience (e.g. *The*

Eye of Mars), and others by involving the performers on stage and leaving the final users of the experience in the role of external observers (e.g., *The Hidden music of Leonardo, Skin awareness, Galileo all'inferno*).

Instead, the only case that excelled in all the *Keys of Immersion*, always resulting in the fourth quartile (>75%) was *OVR Dark*. This is the only VR video game in the sample, and it is interesting how the technological tool (HMD) with the game dimension, creating the so-called *magic circle* around the player, favoured the conditions for immersion in all the different aspects identified. Indeed, the direct involvement of the user, called to explore a virtual space with a clear objective, a quite high level of agency, and within an emotionally triggering setting are all ingredients that can positively affect the feeling of immersion.

Moreover, looking at the ensemble of case studies in the fourth quartile, it is patent how virtual reality, both exploiting head-mounted displays and environmental projections, plays a prominent role. Of course, this technology has the exact purpose of creating a reality in which a user should be captured, but this result might also be influenced by the fact that most of the examples are VR-based. In general, though, it is difficult to identify characterising traits that recur in all these case studies. As it will be presented also in the next chapter, these differ for technologies and tools employed, as well as for content and scope. Therefore, the factors that determined their good performance depend on their specific peculiarities and should be evaluated on a case-by-case basis.

Further considerations on the *Keys of Immersion*, based on the evaluation activity, can be depicted to ensure greater transparency of this qualitative process.

Firstly, it was evident that assessing the case studies without a first-person experience could be challenging. *Keys* like *presence, cognitive and emotional engagement, embodiment*, and *isolation* were the most affected by this issue. When possible, the research team tried to establish more *objective* modalities to guide the evaluation process. For instance, as it was not possible to infer the level of agency that a user could perceive, each number was associated with a predefined meaning for the evaluation of *embodiment* (as explained in section 3.3), while *engagement* and *isolation* aimed at assessing the intentionality of the design team to actively promote them within the design or the objective of the project.

Another factor menacing this study was undoubtedly subjectivity. To balance it, an adequate number of judges were called to perform the evaluation individually. Interestingly, though, the results were homogeneous in the majority of cases (with few cases with a delta of 2 points between the judges' assessments and even more rare ones with higher differences). In this regard, it is interesting to note how the number of senses involved per each case could be differently perceived among the evaluators. Despite it might seem quite an objective measurement, *sensory involvement* scores could sensibly vary for the same case study, denoting how different senses, beyond the most traditional ones, could be envisioned and identified by the judges.

3.5 Discussion

The collection and analysis of case studies have yielded a snapshot of immersive experiences and technologies proposed across various fields. What emerges is the application of these technologies to augment ordinary experiences, fostering a heightened level of user engagement.

Expectedly, though, collecting satisfying data for a comprehensive overview of the case studies proved challenging, although several nuanced questions were included in the questionnaire. In particular, to investigate design processes, actors, and tools, semi-structured interviews were deemed necessary and are presented in the following chapter.

Therefore, in this phase, the analysis focused on the explorable information available, in alignment with the research objectives and conception of immersion.

Interestingly, despite the fundamental role that senses play in fostering immersion, only a few of them (specifically sight and hearing) are usually leveraged. *Presence*, *engagement*, and *embodiment* seem mostly associated with the technologies and tools employed. In this context, VR and AR are undoubtedly protagonists of current experimentations for immersive experiences, possibly obscuring other challenging but potentially rewarding modalities. What can be observed is that few of the case studies collected encourage active interaction modalities, which might be a promising gap to fill, as unsurprisingly, an increased agency can lead to a higher embodiment, engagement, and consequently immersion. Furthermore, the concept of isolation highly reflects on the social dimension, possibly because, on a practical side, it might be easier to envision individual experiences and, theoretically, this reflects the position encountered in literature, indissolubly connecting the concept of immersion with *isolation*.

Evaluating the case studies according to the *Keys of Immersion* framework provided the research team with a clearer understanding of the immersiveness present in the collected case studies and allowed them to concentrate on significant features that seemed actually effective for evaluating immersion. However, some of these dimensions proved challenging to assess without a first-person experience of the case studies.

4 Deepening the investigation of immersive case studies

4.1 Introduction and Methodology

4.1.1 Selection of the case studies for the interviews

To have a more fine-grained overview on the characteristics of immersive case studies that are of interest for the Artcast 4D project, a further qualitative step of investigation was necessary. As anticipated, semi-structured interviews were identified as suitable means to gather insights on elements that usually are not public (like design processes, actors involved and their roles and contribution in the project, more detailed information on the software and hardware used, etc.) directly from the studios and companies who developed them.

Therefore, the initial set of 13 case studies in the fourth quartile needed to be reduced to comply with the time constraints of the WP and to avoid repetitive information. To do so, the case studies were classified according to the technology and tools typology they implemented and, in case they differed, also the modality of interaction and the field of application were considered.

Overall, 7 typologies emerged, as visible in Fig. 21. They are: VR video game (*OVR Dark*); VR projection (*Dataspace - Deep Space 8K, Borderless*); VR interactive projection (*Anima Mundi*); VR HMD (*Museo di Monte San Michele, VR Workshop activities in Polimi, Nefertari Tomb, Mona Lisa VR, Nuii VR Adventure, Dreams of Dalì*); Environmental installation only leveraging sensors and actuators (*Rain Room*); Extended reality (*Collio XR*); and finally, for the peculiarity of *The Dreamachine* case study, an ad hoc category was defined as Mind-based experience.

The ones with the highest immersion value per each category were contacted for the interview. Finally, based on the responses and availabilities of those responsible for the projects selected, it was possible to conduct semi-structured interviews about the following case studies, representing 5 out of the 7 categories identified:

- *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).

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 Dalì	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

Fig. 21: Table showing the typologies of the case studies from the fourth quartile.

4.1.2 Selected case studies overview

To introduce the case studies that were later deepened through the semi-structured interviews, the subsequent paragraphs provide a synthetic description, as emerged from the data previously gathered and emphasizing the research items of interest. These include (when available) the technologies and tools utilised, the interaction modalities employed, the target users, and the immersive characteristics of the experiences or installations.

OVRDark by Quasar Dynamics

The immersive video game company Quasar Dynamics, based in Valencia, has developed *OVRDark* (Fig. 22), a Virtual Reality video game that will be released in late summer 2023. The horror video game has been selected as very engaging on both cognitive and emotional levels, thanks to the escape room structure and the horror background and plot of the video game itself.

Users. *OVRDark* requires users to be familiar with using the PlayStation VR tool and have an interest in engaging with immersive video games and, especially, with the horror-themed escape room narrative. However, *OVRDark* does not have a specific target audience, and the experience is designed to be enjoyed by a wide range of users.

Interaction modalities. In the *OVRDark* VR video game, the users get in touch, in terms of tangible touchpoints, with the head-mounted display and the joysticks. These stimulate users' experience through the sense of sight and hearing. Touch is also involved through vibration, the haptic feedback of the joystick. In *OVRDark*, users interact with several virtual touchpoints. From those typical of video games (menu, bottoms, options, etc.) to the digital space and objects they can explore. The shift of focus and high level of engagement are intrinsic requirements of games. As well, a strong cognitive and emotional involvement is conveyed by the nature of the content itself, related to a horror escape room-like situation.

Fields and cross-fields. In this case, the application domain of the case study is primarily within the gaming industry, enclosed within the broader entertainment field. The experience of *OVRDark* is specifically designed to cater to gaming enthusiasts, capitalising on their interest in immersive and interactive entertainment.

Fig. 22: Representative image of the OVRDark experience. Courtesy of Quasar Dynamics.

Museo di Monte San Michele by Ikon

Museo di Monte San Michele is a museum that collects memories and artefacts about the battles that took place in Monte San Michele during the First World War (Fig. 23). During the first years of the conflict, this mountain became one of the principal war theatres between the Italian and the Austro-Hungarian army. The place is located in Friuli-Venezia Giulia (northeast region of Italy), in the Sagrado municipality. (*Monte San Michele | Atlante Della Grande Guerra a Nord-Est*, n.d.)

The museum website offers a clear description of the overall immersive experience the visitors have inside the museum itself (Museo del Monte San Michele, n.d.). Visitors can enjoy a varied array of digital and interactive contents inside the museum. In the pedestrian outdoor path, they can scan QR codes and activate AR contents referring to the history of the places through their smartphones. However, both the evaluation and the following interview focus on the VR experience. Indeed, in a room called VR 360, fifteen HMDs are deployed at stations and visitors can use them to watch 360

videos with audio content in order to immerse themselves in some moments of the battle and during the flight of an Italian pilot.

Users. *Museo di Monte San Michele* is a case study that has not a specific target audience. Everyone can access the museum and enjoy the immersive content proposed.

Interaction modalities. Referring to the VR field, Ikon's case study *Museo di Monte San Michele* gives the users the possibility to interact with head-mounted displays, but without joysticks. Wearing them, they change their point of view by moving and rotating their head. The virtual position, however, is not modified, and the users follow the unfolding of the story and scenario as they were previously designed. Here the cognitive and emotional involvement is given by the emotiveness of the stories told, from real war situations. The experience is individual, and the users are engaged just as viewers and listeners.

Fields and cross-fields. The field of reference of the case study is cultural heritage, specifically referring to war history. Gorizia territory has been one of the hot spots in the First World War for the Italian side.

Fig. 23: Virtual Reality experience at Museo di Monte San Michele. Courtesy of Ikon.

Dataspace - Deep Space 8K by Ars Electronica FutureLab

Among the several exhibitions that took place in *Deep Space 8K*, within the Ars Electronica Centre in Linz (Austria), the *Dataspace* installation has been selected as a specific case study as it effectively portrays the potentialities of the space (Fig. 24).

Deep Space 8K is a room equipped with high-quality technological tools, such as projectors, audio systems and laser-tracking systems. The centre uses it as an exhibition space for immersive and interactive contents, hosting several artists, studios, designers, and companies to showcase their contents. The Ars Electronica Futurelab team curates the location with the application and handles the maintenance of cutting-edge technologies. (*Deep Space 8K*, n.d.; *Deep Space 8K*, n.d.-b)

Specifically, *Dataspace* projects data about the profound impact of the current conflict between Russia and Ukraine in a 3D view. Visitors are immersed in a fact-based data space, with a totally different fruition of journalism. (*Dataspace: Global Impact of Russia's War on Ukraine*, 2022)

Users. *Dataspace* is an immersive installation referring to media data given into a different visualisation and interaction. No specific target audience has been identified, as the experience is designed for a wide range of people interested in the content displayed.

Interaction modalities. *Dataspace* elicits a strong interest in surrounding visual effects and promotes the reading of data: from 2D on screens or paper to 3D immersive effects on projected surfaces. Here, users can move throughout the space but they cannot interact with the content. Sound also stimulates the cognitive involvement of the users.

Fields and cross-fields. *Dataspace* encourages data visualisation and media information reading through an immersive experience. The case study refers to the mediatic fields with new ways of interacting with the given information.

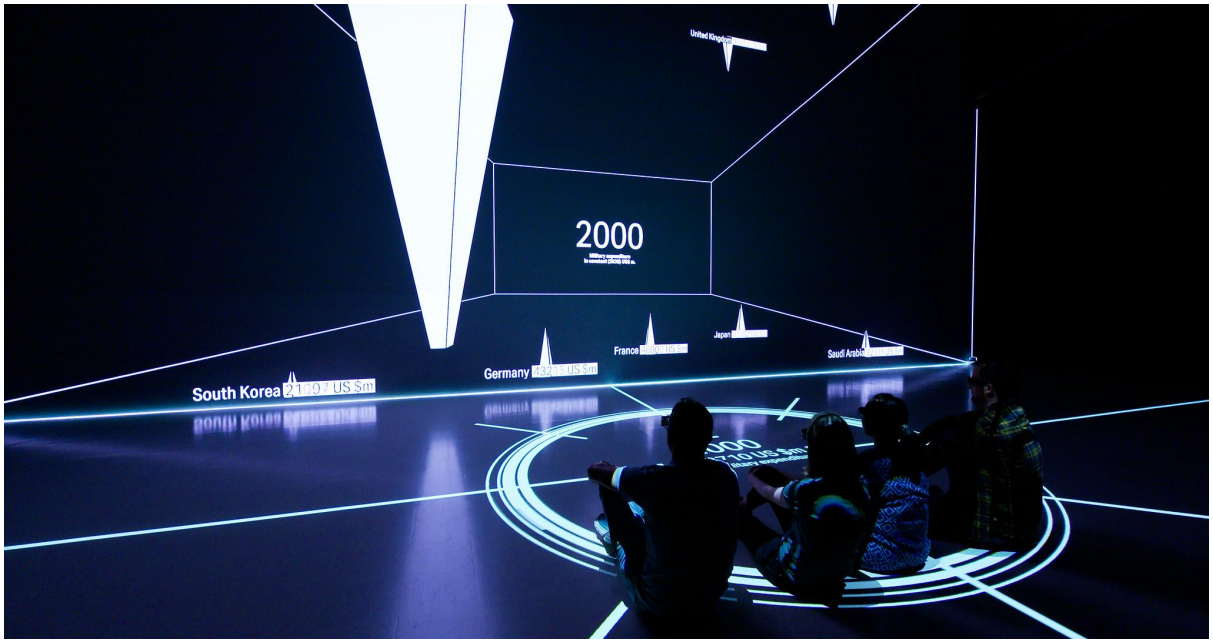


Fig. 24: Dataspace project created by Ars Electronica FutureLab. Courtesy of Nikkei Innovation Lab (Hiroyuki Watanabe, Nobuyuki Oishi, Takeshi Yamada, Akihito Takei, Masami Fujita), Ars Electronica Futurelab (Arno Deutschbauer, Manuel Dobusch, Nicolas Naveau, Hideaki Ogawa, Raphael Schaumburg-Lippe, Julian Zauner). Image credits of Raphael Schaumburg-Lippe.

The Dreamachine by Collective Act

In 1959 artist-inventor Brion Gysin developed a new way to interact with light: *The Dreamachine*, a mechanised structure that changes light pattern in front of the spectator, who enjoys the changing light with her eyes closed (Ryan, 2023). The experience is immersive and personalized to each user, who can interpret her own vision of the light movement.

This invention has been taken and developed in a modern way by the artistic director Jennifer Crook, who later created the Collective Act group in order to work on *the Dreamachine* project.

As shown in Fig. 25, the immersive experience consists in a room in which visitors are welcomed to lay down and close their eyes: through audio and light experiences, they see different outcomes and immersive visions (*About - Dreamachine*, 2023. The installation is ready to travel around Europe: since today it has been held into UK only.

Users. *The Dreamachine* is targeted toward users who possess a sense of curiosity and are eager to experience it first-hand. Additionally, researchers who are interested in analysing the results and impressions reported by the users themselves are also a target audience for this experience. *The Dreamachine* offers the integration of

research programs, allowing researchers to incorporate their studies and investigations within the experience.

Interaction modalities. *The Dreamachine* is a unique case study between the ones collected inside the consortium: here the interaction leverages light and sound patterns, excluding digital, virtual, or advanced technologies. Users enjoy the immersive environment, laying into a room and closing their eyes. What is perceived through the closed eyes while the lights change is the experience itself. This is very personal, and a research activity is going on from the collection of feedback and outputs from the visitors themselves. Even through closed eyes, sight plays an essential role as sense, as well as hearing.

Fields and cross-fields. Multiple fields are involved in this case study. From scientific research to the artistic and entertainment scopes of the installation itself.

Fig. 25: The Dreamachine immersive experience. Courtesy of Collective Act.

Collio XR by Ikon

The selected case study refers to another work by Ikon Company. *Collio XR* is a project collecting several immersive solutions designed to enhance Collio Goriziano territory

visitors' experience (Fig. 26). Collio Goriziano is located in Friuli-Venezia Giulia (Italy), near the border with Slovenia.

Through the program *CarigoGreen*, funded by the Carigo Foundation, with Banca Intesa San Paolo, Ikon has been asked to work on this local territory. (*CARIGOGREEN: Dove La Tecnologia Incontra Il Paesaggio*, n.d.)

They designed a mobile app that visitors can download to enjoy sound contents related to different walking and biking paths inside the region. These include curiosities, stories, and characteristics of the zone (*Fondazione Carigo + Intesa Sanpaolo / CollioXR*, n.d.). Moreover, graphic totems have been displaced in strategic points and visitors can use their mobile phones to scan them and enjoy AR contents, always related to stories from the territory. Significant places have been dedicated to the fruition of Virtual Reality contents, by placing smartphones inside a cardboard box provided to the users before the experience.

Gamification strategies have also been included. The more visitors use the app (visiting locations, walking through paths, and so on), the more points they get. Finally, badges are released to those who gain enough digital points. A geolocalization system informs visitors through the mobile app on their position during the walking path, reporting all the traces and extended reality enjoyable points.

Users. *Collio XR* is a case study that caters to users who are interested in landscape appreciation and cultural enrichment of a specific region. The target audience includes individuals with a penchant for outdoor activities such as trekking and walking, as well as those who appreciate immersing themselves in the cultural aspects of a given territory. There are no specific limitations regarding the audience, as the experience is designed to be enjoyable for a diverse range of users.

Interaction modalities. *Collio XR* presents multiple immersive experiences: when using the mobile app on the walking paths, the users can primarily interact with the content through headphones. The cognitive involvement is given by the stories and curiosities told while walking. AR touchpoints let the users interact with the smartphone first, using it as a screen for reality, and consequently with landscape elements as well. Ultimately, for the VR part, they are provided with cardboard boxes to use the smartphone as visors, with virtual content triggered in strategic points. The VR experience does not allow users' personalization but, rotating and moving their heads, they can enjoy the 360 or 180-degree content.

Fields and cross-fields. The focus is on cultural heritage. *Collio XR* aims to enhance the cultural and historical aspects of a territory, enriching the experience of users who engage with it. By emphasizing the cultural and historical points of interest, *Collio XR* offers an immersive and enriched experience for users, allowing them to immerse more deeply with the landscape and its cultural significance.

Fig. 26: Collio Extended Reality experience. Courtesy of Ikon.

4.1.3 Interviews structure and supporting protocol

The primary goal of the semi-structured interviews was to deepen the qualitative pieces of information about the design processes characterising the case studies, that usually are not publicly available. The interview is envisioned to progress from a general overview to specific details, systematically addressing each aspect step by step. Therefore, the attention of the research team first focused on the definition and unfolding of the process (steps 01 and 02), including the actors that were involved and in which ways (step 03), the hardware and software implemented (step 04), and the perspectives of the interviewees about the values and pain points they encountered (step 05).

Figma (https://www.figma.com), a collaborative web application, was used to help guide the interview and gather information with real-time feedback from the interviewees. Indeed, five different canvases, one for each step to touch during the interview, were created to display the topic under investigation during the online meetings and to provide a space where the abstract concepts discussed could assume a visible and shareable form to facilitate the conversation and mutual understanding. Specifically, two researchers handled the interviews, one directly interacting with the interviewees, while the other was working in the back-end to visually report the responses on the canvases so that everybody could see them in real time.

The description of the contents and communication of each step follows.

Step 01. The semi-structured interview opens with a broad overview of the design process followed to realise the case study (Fig. 27). In particular, four distinct graphic representations of possible processes are suggested:

A) *Linear*, representing a process where each phase follows the previous one in a sequential manner.

B) *Iterative*, illustrating a situation in which process phases are continuously improved and reviewed.

C) *Spiral*, identifying a hybrid approach combining elements from both the linear and iterative processes.

D) *Highs & Lows,* emphasizing a path full of hiccups, as a variation of the previous ones more than a different one, with which the interviewees could identify themselves more.

In addition, the possibility to freely represent one's own process is provided for further personalization in case none of the proposed ones would be satisfying.

Once the most suitable process representation is selected and reported in the *working area* of the canvas, the start and end dates or periods can be included to provide a clear timeline for reference.

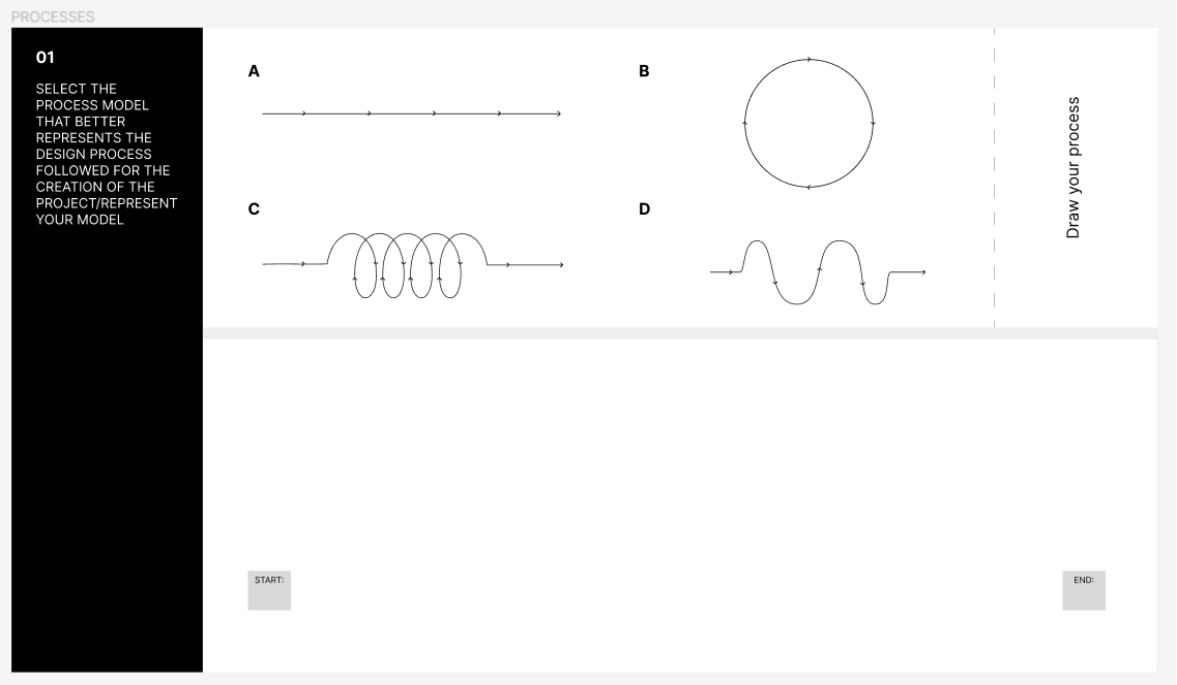


Fig. 27: First step into the interview support material designed for the interviews activity. Here the interviewee is asked to indicate the most suitable graphic representation for the overall design process, or to draw a new one more representative.

Step 02. Subsequently, a more detailed depiction of the process is inquired, in the attempt to identify and understand the major steps characterising it. A set of circular labels can be customised to depict all the phases of the design process and they need to be placed on the graphic path previously selected or elaborated (Fig. 28). This structure of the canvas is meant to help the interviewees recall, reconstruct, and systematise the process that led them to the realisation of the project in question, while giving them the possibility to richly articulate and describe it, to collect as much information as possible.

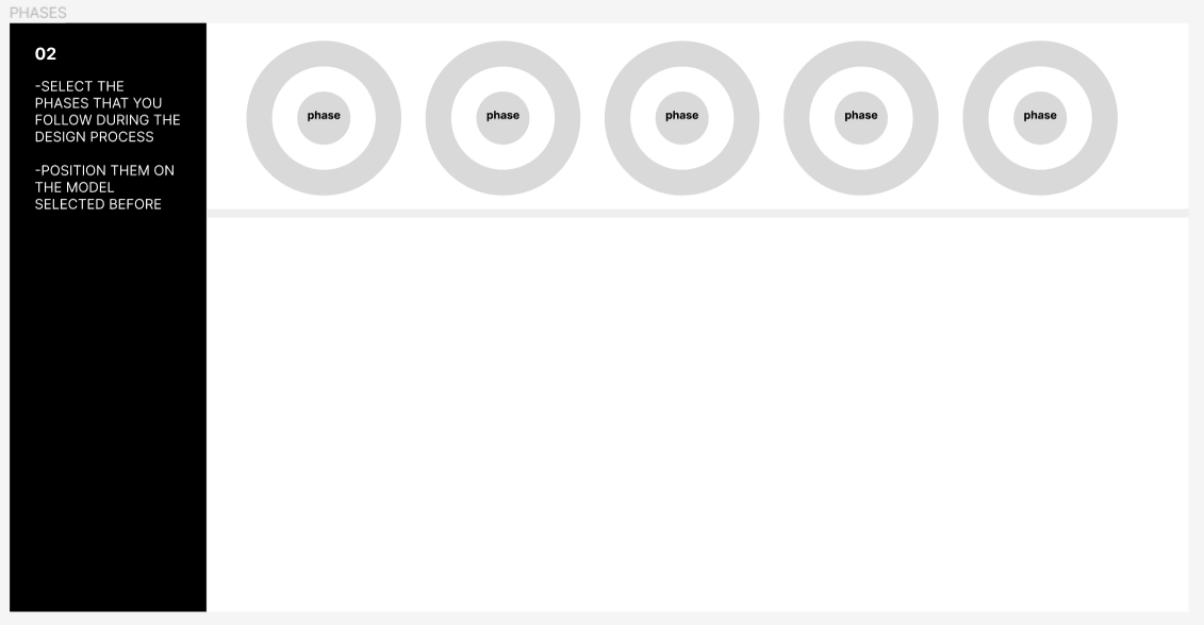


Fig. 28: Second step into the material structure: here the interviewee is asked to individuate the different phases of the design process, giving them a title.

Step 03. Following the delineation of the overall process, the focus shifts toward the actors. In particular, all the actors involved in each phase can be listed according to the macro categories suggested in the canvas (Fig. 29), which serve as references for the interviewees to recognize those relevant in their case, or adding further roles that best fit the case study.

Then the actors, specifically identified, can be assigned to the phases in which they took part in some way, while the interviewer solicits articulated explanations.

The overall process is subsequently reviewed to ensure accuracy and completeness of the information captured.

Fig. 29: Into the third step, the interviewee is asked to recognize the different actors involved during the single previously individuated design process phases.

Step 04. Going into an increasingly detailed level, the interview explores the tools and technologies that supported the design process. In particular, the interviewees are prompted about software, hardware or any other support used by the identified actors throughout the different phases of the project.

While they can freely list them and explain how and why they were used, the researcher in the back-end has predefined markers at disposal and can insert yellow boxes indicating software tools (encompassing categories like graphic production, sound production, 2D animation, 3D modelling, 3D animation, 3D scanning, video capturing, video editing, coding, design, video game engines, rendering, data visualisation, and AI), pink boxes representing hardware tools (including sensors, actuators, haptic devices, Kinect, head-mounted displays (HMD), joysticks, projectors, monitors, tablets, body tracking systems, light systems, Play Station, and audio systems), and green boxes depicting design tools (e.g., brainstorming, focus groups, workshops, interviews, questionnaires, the Five Ws technique, moodboards, personas, post-it notes, blackboards, online user experience (UX) tools, and cards) to map those that are mentioned directly on the process path under construction.

Additionally, a red star flag can be placed to indicate open-source resources (Fig. 30).

Fig. 30: Fourth step is about assigning each actors the specific tool (hardware, software, design tools) used during the specific design process phase.

Step 05. Finally, as the overview of the design process should be complete for what is relevant to the investigation, conclusive remarks are asked about the values and pain points they recognize throughout the development project. This step allows for a critical evaluation of the strengths and weaknesses of the design process, enabling the identification of the elements that positively contribute or pose challenges to the realisation of immersive installations or exhibitions (Fig. 31).

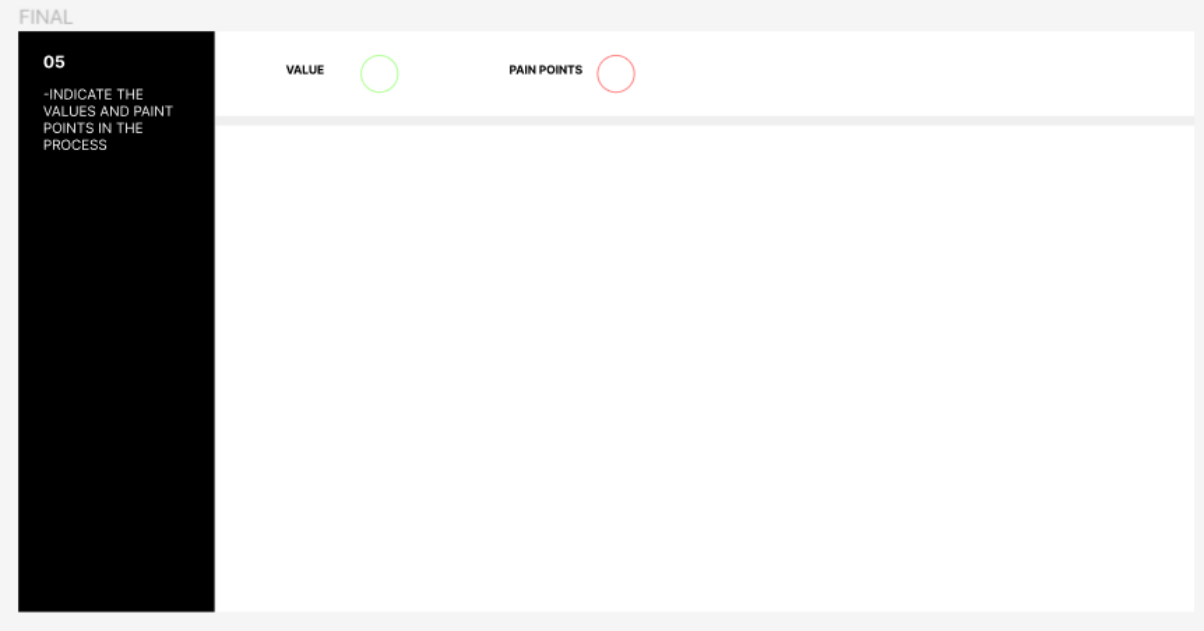


Fig. 31: Fifth and last step asks the interviewee to recognize values and pain points of the overall design process, including the phases, actors involved, tools used, in front of the graphic output of the interview material.

4.2 Interviews results

Thanks to their helpfulness and availability, the semi-structured interviews involved individuals that, in various capacities, contributed to the selected case studies. Specifically, they include: game developer Anthony Leites Derossi and business developer Nicolas Terol, both associated with Quasar Dynamics, for *OVRDark*; Enrico Degrassi, CEO of Ikon company, who provided insights both on *Museo di Monte San Michele* and *Collio XR*; Hideaki Ogawa, the Director of Ars Electronica FutureLab and Director of Ars Electronica Japan, who contributed for *Dataspace*; and Jennifer Crook, CEO and Art Director of Collective Act, who shared her expertise on *The Dreamachine* project. These interviews provided valuable first-hand information which is reported following the structure of the interviews themselves, depicting the design process, the actors involved, and the technologies and tools used.

4.2.1 Quasar Dynamics - OVRDark

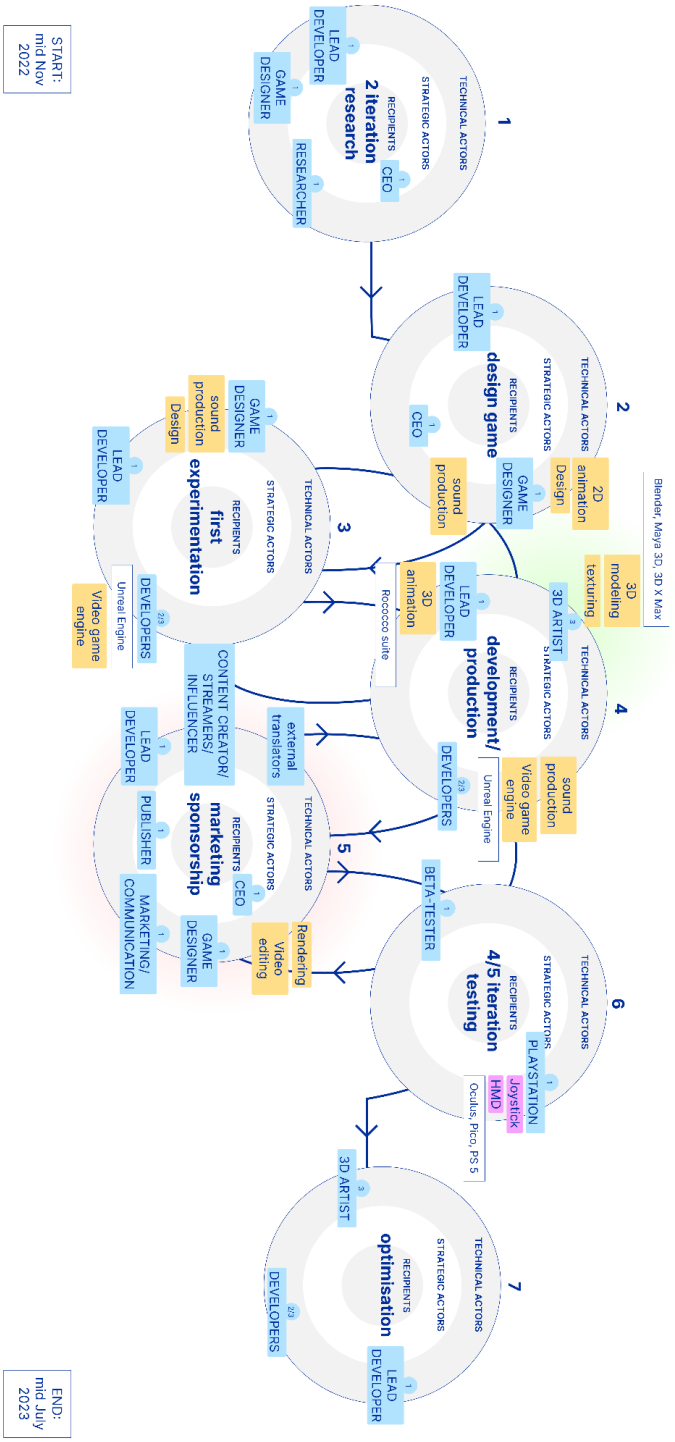


Fig. 32: Schematic representation of the process, phases, actors and technologies and tools of the OVRDark case study.

Design process

During the initial inquiry into the most suitable graphic representation of the design process used in the creation of the *OVRDark* video game, Anthony Leites Derossi and Nicolas Terol identified three options: the fully-iterative model, the spiral model, and the highs and lows representation (B-C-D). They reached a consensus on the iterative nature of the design flow. However, Anthony also emphasized the challenges encountered throughout the design process due to the numerous iterations involving technology, which led him to align more with representation D, characterised by ups and downs.

Continuing the discussion, the iterative nature of the spiral process was further highlighted and found to be aligned with the hundreds of iterations undertaken during development. A spiral design process has finally been selected for the *OVRDark* case study. It started with a first "Research" phase that they had to iterate twice according to the interviewee from Quasar Dynamics. The research activity has been carried out by a researcher, a designer, and a developer, together with the CEO. A phase of "Design game" followed, where the effective output has been outlined to go for the next phase "First experimentation" with developers and designers. In this context, the interviewees emphasized that they had to revisit and incorporate the "Research" phase multiple times within the iterative design process. This indicates the significance placed on conducting thorough research and gathering insights throughout the design iterations. The iterative nature of the design process allowed for the integration of the research findings, enabling the team to refine and improve the game development based on the acquired knowledge and understanding. The output of this phase lays the foundation for the next step, "Development / Production", where the developers and 3D artists actually developed the video game. The "Marketing and sponsorship" phase saw the preparation of promotional and communication material, but also of the accessibility features for the game itself (for instance, the translation in other languages). The countries of reference are Italy, Germany, France, Portugal and UK in Europe and USA and Brazil in America: in order to approach these foreign countries, their plan is to contact influencers, content creators, online and offline media as well, all regarding VR and horror video game fields. Next, we found an iterative "Testing" phase – which they declared included four to five checks – with a beta-tester provided the last changes to the design of the game. Ultimately, it was finalised into the "Optimization" phase. The interviewees report a very long iteration also into this last phase, due to the overall quality assurement details to carry on. The overall design process lasted from about mid-November 2022 to mid-July 2023. The only value point recognized by the representatives of Quasar Dynamics was the contribution of 3D artists during the "Development/ Production" phase. One notable pain point in the overall design process is identified in the "Marketing and sponsorship" phase, concerning the challenge of identifying a suitable foreign press or media partner who was willing to collaborate and promote the video game. Establishing partnerships with media outlets in foreign markets can be difficult due to language barriers, cultural differences, and varying media landscapes.

Actors involved

The actors involved in the design process of *OVRDark* are both internal and external to the company. The CEO has been involved in several phases, especially at the beginning, for strategic decisions. A team of developers, with one lead developer, 2/3 video game developers and one game designer, obviously had an important role through the process for the realisation of the video game. In this project, there is a convergence of multiple roles carried out by the same individuals. For instance, the designer who possesses expertise in 3D skills takes on the responsibility of incorporating architectural elements into the construction of the 3D house environment. This merging of roles highlights the versatility and multi-disciplinary nature of the team members, where they bring together various skill sets to fulfil different aspects of the project. Such integration of skills ensures a cohesive approach and efficient coordination within the development process. In the last phase, three 3D artists have been involved, and 1 beta-tester has helped during the "Testing" phase. When considering the value point of the design process, the presence of 3D artists collaborators has been identified as critical. Their expertise and knowledge have played a fundamental role in establishing the high quality of the video game. The skills brought by these 3D artists have significantly contributed to the visual appeal, realism, and overall aesthetics of the game environment. Additionally, the "Marketing and sponsorship" phase required the intervention of external resources such as influencers, content creators, and streamers for promotion. A translator and a publisher were also essential. Moreover, a person from the marketing/communication team was involved. External roles include also the influencers and content creators paid in order to promote the videogame.

The main roles involved reported skills from designing and developing video games in extended reality. While secondary roles intervened just for the specific phases in which they were needed (marketing, testing, etc).

When evaluating the value points within the design process, one of the most impactful factors recognized is the effective workflow and collaboration between colleagues. The seamless exchange of skills and knowledge among team members adds substantial value to the project. The expertise contributed by one colleague serves as a value-added asset for another, leading to a cohesive and comprehensive development process. Furthermore, the limited number of colleagues fosters a more intimate and human connection between team members, promoting a higher quality of collaboration and fostering a sense of friendship among them. This positive working dynamic is seen and recognized as a remarkable value point from the interviewee.

Technologies and tools

OVRDark is an immersive virtual experience enjoyable by players through head-mounted displays. The tools used throughout the production phases of the experience are related to video games and virtual reality contents: 3D modelling, 3D animation, video game engine, texturing, and rendering software. Sound production software

tools were also necessary and, as declared by the interviewee, the sound output contributes strongly to the overall quality and effectiveness of the VR game, resulting in a more immersive and engaging experience for users. A significant pain point within the tools used is represented by the limited connectivity and knowledge exchange among users in the Unreal Engine community. This strictness hinders a seamless and widespread collaboration, making it challenging for users to share insights, troubleshoot issues, and exchange best practices effectively.

4.2.2 Ikon - Museo di Monte San Michele

Design process

When discussing the spiral process, Enrico Degrassi, Ikon CEO, has consistently referred to it as the optimal graphic representation for their case studies. The interviewee emphasized that the installation was produced in 2017 and, during this period, the design team encountered various complexities. Indeed, dealing with stereoscopic cameras, 3D post-production activities, and the intricacies of Virtual Reality systems posed significant challenges. These complexities necessitated multiple iterations and attempts throughout different design process phases to arrive at effective solutions. As a result, the iterative representation emerged as the most suitable approach for capturing the dynamic nature of their design process, as it allowed them to refine and improve their techniques incrementally, ultimately leading to the successful realisation of the installation.

For Museo di Monte San Michele he pointed out a first phase, the "Brief", to which internal (the CEO himself, also covering the role of Creative Director, the account manager, and the project manager) and external actors (commission, municipality, related association) took part. In this phase, the project objectives were discussed, steering to the next phase, called "Define". That was the moment in which the strategic requirements for the design output were identified, in collaboration with the external stakeholders and other figures such as the 3D senior artist of Ikon and the external expert historian. The "Design" phase followed, with the focus moving to the UX and visitor flow of the experience and the technological side of it. A storytelling expert, director, and software architects participated in this phase. In the "Historical research" phase the process focused on the content creation for the installation; the "Immersive production" step focused instead on the production of the VR content (with the 3D artists team, the sound engineer and light designer), video production part (director, visual effect expert and the camera operator. Next, the "Testing and refinements" phase followed, with a team of 10/15 beta testers useful to effectively suggest confirmations and modifications to the experience. This iterative process led at the end to the "Delivery", with the installation deployed in the museum and the final output shown to the stakeholders involved. The project lasted from March 2017 to October of the same year. The interviewee recognized the technical production as a pain point as it required a huge amount of time.

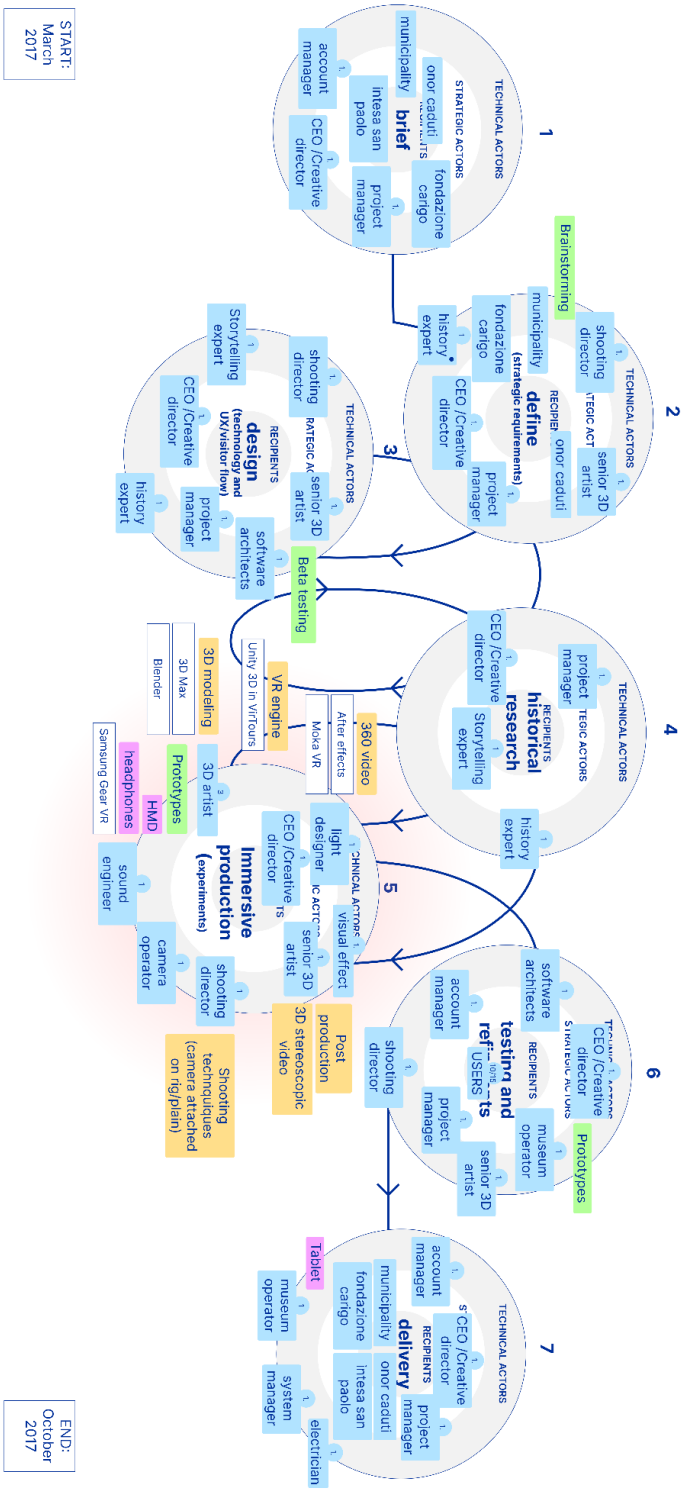


Fig. 33: Schematic representation of the process, phases, actors and technologies and tools of the Museo di Monte San Michele case study

Actors involved

Ikon Company can rely on multiple professionals and actors. Depending on the project's output and needs, and on the unfolding phases, the interview demonstrated that several different actors were involved. First of all, the CEO, also acting like Creative Director, was present in almost every phase of the project. Permanently, the project manager followed them all. In the first phase of *Museo di Monte San Michele*'s project external stakeholders were invited at the table: Fondazione Carigo and Intesa San Paolo bank are recognized as the commission, the municipality of Salgado and the association Onor Caduti, were instead depositaries content of the case study. Enrico Degrassi, CEO and Art Director of Ikon company (*Ikon*, n.d.), during the interviews told the Fondazione Carigo (*Fondazione Carigo*, n.d.), together with Intesa San Paolo bank (*Persone E Famiglie*, n.d.) and Onor Caduti group (*Ufficio per La Tutela Della Cultura E Della Memoria Della Difesa - Difesa.it*, n.d.), contacted the immersive experiences and installations company in order to redesign the overall Museo di Monte San Michele museum experience. In addition, the Sagrado municipality (*Comune Sagrado*, n.d.) participated in the first phases of the redesign process for the old war museum. From Ikon's side, the account manager played an essential role. The next phase, to define project guidelines and requirements, also saw the presence of a history expert (external resource involved for that specific case), the director and the senior 3D artist. For the design phase, external actors left the place for the storytelling expert and software architect, working with the rest of the team already cited. These two figures were crucial during the historical research phase, while in the immersive production step more technical roles were essential: visual effect expert, three 3D artists, a light designer, and external resources added such as a camera operator for the video taking and a sound engineer for the installation.

A museum operator and a team of 10/15 users were eventually involved into the testing phase, along with managers and the director, 3D artist and software architect. The "Delivery" phase saw the project stakeholders and the museum curator again around a table, together with an electrician and system manager for the overall installation setup. To facilitate easier content management for the museum operator when configuring the VR headsets, the Company implemented a cloud system linked to an external tablet that the operator could use. This cloud-based solution allowed the operator to remotely access and control the content on the VR headsets without the need for direct physical interaction with each device. By using the external tablet and cloud system, the museum operator could efficiently update, organise, and customise the content displayed on the VR headsets, enhancing the overall user experience and simplifying the management process.

Technologies and tools

The project for Museo di Monte San Michele required many technological competencies and components. However, only the VR installation was the main object of the interview. For this, the company created and developed VR content (360 videos and 3D animations) to be deployed into several head-mounted displays

inside a specific room of the museum. Sounds were available through headphones connected to the visors.

Unique shooting techniques were employed to capture the video scenes and make them available in stereoscopic view for the immersive experience. To achieve this, the team installed a camera on the wings of a small airplane to capture the necessary 360-degree videos. This innovative approach allowed them to obtain immersive and realistic footage, used to enable users to feel fully immersed in the virtual environment during the experience. The unconventional use of the airplane's wings as a filming platform showcases the team's creativity and commitment to delivering a truly captivating and immersive experience for users.

A post-production software was needed for the refinement of the content, while a 3D modelling and a VR engine software have been adopted to create animations.

4.2.3 Ars Electronica FutureLab - DataSpace

Design process

The process followed by this case study was described as iterative and characterised by circular graphics.
Specifically, for *Dataspace*, a first "Inspiration" phase opened the design process, also called "Creative compass". Here the goal was to extract creative questions to be answered in the next step. Next, the second phase was "Question" -or "Future vision" – with external and internal stakeholders, respectively, the media Company they were working with and the project manager, the CEO of Ars Electronica FutureLab, the art director, the curator, a strategic developer, and a researcher. Here the goal was to extract the concrete ideas to discuss in next phases: the deliverable comprehended strategy, planning and also sketching vision guidelines in order to facilitate further discussions. At this stage, the design process encompassed a brief and concept phase, iterating between different stakeholders and research activities to better define the outputs, through workshops and online UX design tools. Next, a "Research and development" phase, with developers, designers, and a team of content management, started materialising the project, discussing about feasibility and providing solutions. Another phase, "Prototype" -or "Production"– saw the final outcomes of the activities with the involvement of the same developers and designers' teams. Then, the case study could be tested during the phase called "Dialogue" or "Testing" when it underwent different iterations with questionnaires until the testing confirmed a satisfying quality of the outcome. It took about one year to complete the process, from September 2021 to September of the next year.

The "Inspiration" and "Dialogue" phases have been recognized as value points for the design process due to the good workflow executed; while the pain points related to the difficulty in balancing data and visual effects, and the representation of the simulation into reality.

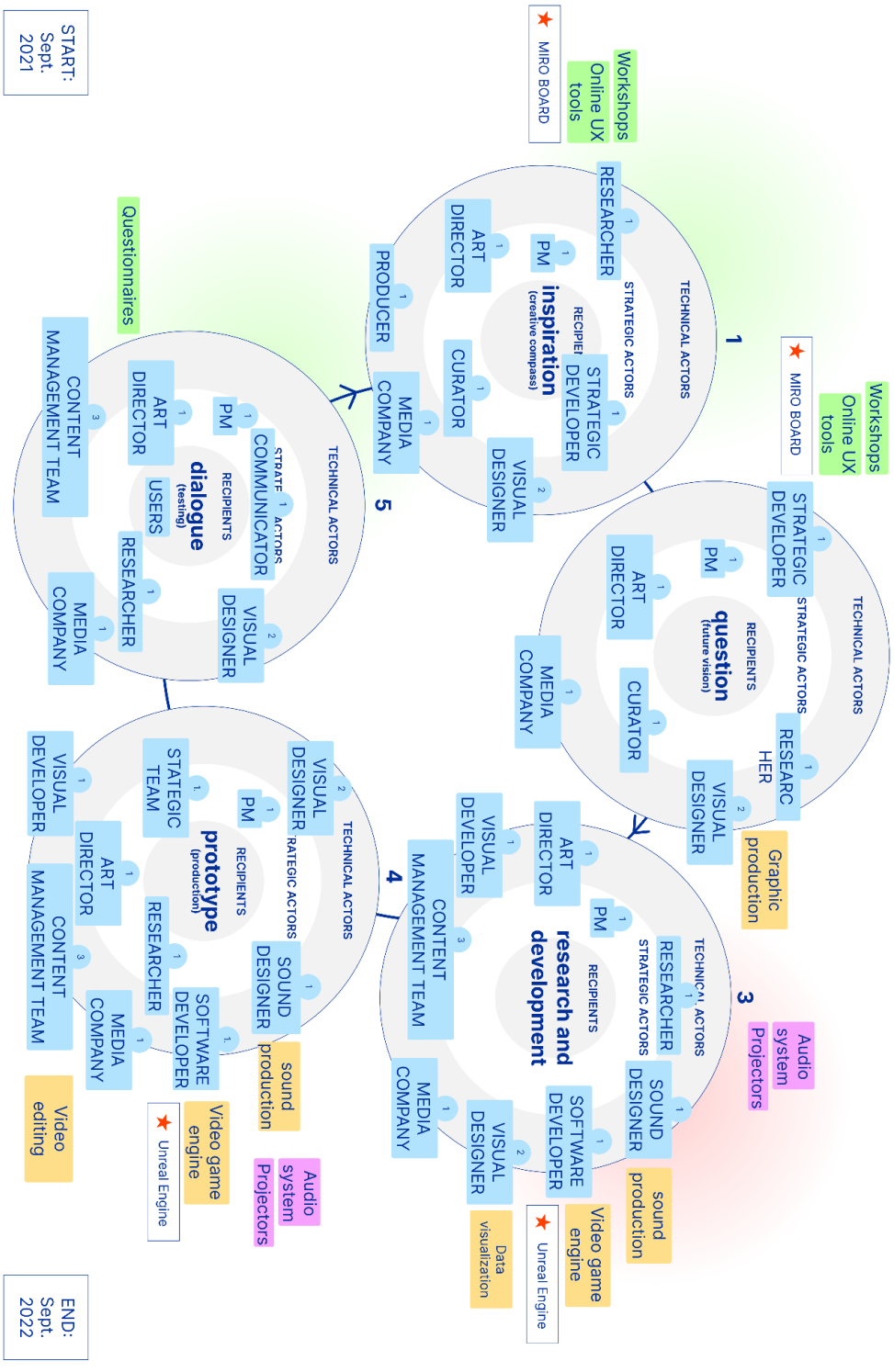


Fig. 34: Schematic representation of the process, phases, actors and technologies and tools of the Dataspace case study.

Actors involved

DataSpace involved different figures from Ars Electronica FutureLab in the design process: the art director, the project manager, one to two visual designers, and a researcher have followed all the phases. As well as these internal resources, a representative of the media company they were collaborating with followed all the process. In the first phases, a curator and a strategic developer were present; a producer has been involved in the very first phase regarding the "Inspiration" session. In the "Research and development" phase, some more technical roles have been added: a sound designer, a software developer, a visual developer. Here we see two visual designers and the presence of a content management team made by three people. A strategic team was also introduced into the "Prototyping" phase, working with the technical roles previously cited. In the last phase, the "Dialogue" step, a communicator was added to the process.

For the overall process it is interesting to note the strong presence of a management team: visual designer and researcher followed all the phases with the managers.

Technologies and tools

Ars Electronica's case study *Dataspace* is based on the use of projected content on surfaces, making users feel immersed in the data on the walls. The content was distributed through projectors strategically positioned inside the room, and obviously sound surrounded the visitors. The contents characterising the experience were designed and developed using software for graphic production, video editing, game engine (such as Unreal Engine), and sound production.

4.2.4 Collective Act - The Dreamachine

Design process

Jennifer Crook, before constituting the Collective Act group, started the creation of *The Dreamachine* in November 2020. Step by step, several external partners and funds have been reached and the group expanded into the Collective that works behind the immersive installation. The design process ended in May 2022. The overall design process was acknowledged as iterative, with the spiral graphic model providing the most suitable representation. Each step informed the next, creating a continuous feedback loop that allowed for experimentation and improvement throughout the development.

The first phase, recognized as the "R&D" phase, included Crook as the director, a sound designer, a scientific expert, an architect, and an engineer to set the bases for the design process and collect ideas to validate in the next phase, "Proof of

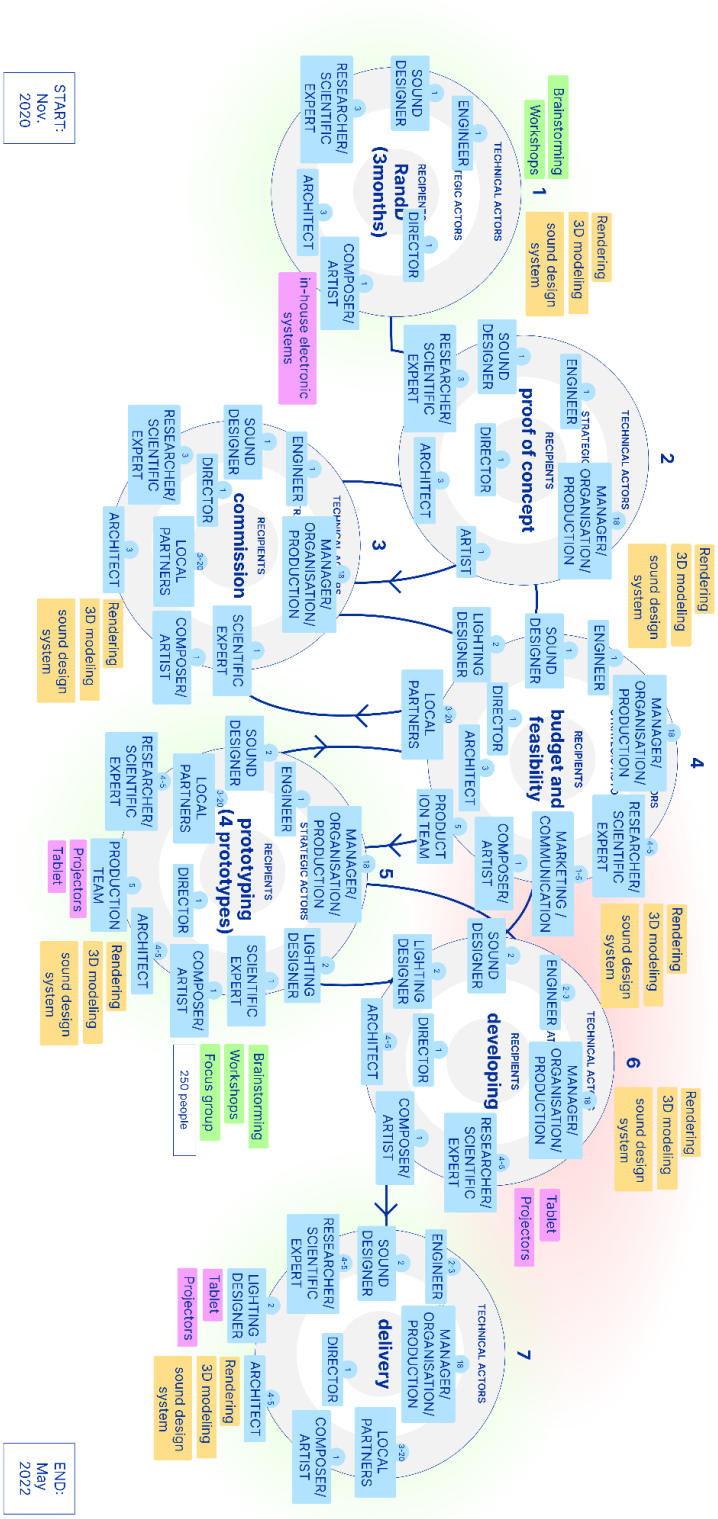


Fig. 35: Schematic representation of the process, phases, actors and technologies and tools of The Dreamachine case study.

concept". Here the team expanded and the output was delivered to the commission in the next step (called "Commission" as well). A "Budget and Feasibility" phase followed the verification of the overall design concept, and production teams started working on the project realisation until the "Prototyping" phase, which involved many actors. More precisely, a large group of people was invited to focus group sessions. The "Developing" phase moved toward the final validation and development for the overall experience, which was finally closed in the "Delivery" phase. Value points referring to the workflow of the resources involved have been recognized into the workflow, specifically in "R&D", "Prototyping" and "Delivery" phases. While pain points mostly concerned time and financial resources devoted to the "Budget and feasibility" and "Developing" phases.

Actors involved

The Dreamachine case study has involved a considerable number of professionals in the design process. In general, architects, artists, designers, engineers, researchers, scientific experts, and sound designers were actively involved in all stages of the design process. The interviewee emphasized that these actors could not be strictly classified as either technical or strategic contributors, as they seamlessly interchanged their roles due to their high level of involvement in the project. The entire team, comprising all these parties, convened weekly for a span of two years to stay updated and work collaboratively on the project.

From the early stages of the project there has been the chance to grow and expand the partners and figures engaged. The "R&D" phase involved the director of the project, an engineer, a sound designer, a composer/artist (Jon Hopkins) and a team of 3 architects and 3 researchers from scientific fields. The funds collected step by step let the team enlarge, reaching a total of 18 people with producing / organisational roles during the "Proof of concept" phase. In the next phase "Commission", several local partners (from 3 to 20) have also been involved. The "Budget and feasibility" phase needed the addition of other 4/5 researchers, a team for marketing and communication (from 1 to 5 people), two lighting designers, a production team of 5 people, and the presence of the previously involved roles. This was the team that instructed, designed, and developed the experience of *the Dreamachine* from this point until the "Delivery". The interviewee reported an increase for the number of people involved, with the same roles and skills, for the "Prototyping" phase, in which also 2500 participants were involved in focus groups.

When presenting the project at various events, including science and arts festivals, the number of collaborators involved has been significantly expanded. Indeed,

Collective Act collaborated with venues, local authorities, and local groups to deliver the immersive experience in different locations. The external collaborators contributed to the on-site delivery of the project. During these events, the number of team members working on the project ranged from three to six, and in some cases, it increased to as many as 20 team members during the actual delivery phase. While the Collective Act is based in London, they successfully produced the experience in four different cities in UK. In each city, they partnered with a host organisation or partner who actively collaborated with them to ensure the smooth execution of the project on the ground.

Technologies and tools

The Dreamachine immersive installation presents the visitors with a light and sound system to let them feel immersed. The main software used include those acting on light pattern movements and sound production. During the interview, 3D modelling and rendering software tools have also been cited because of the material produced for strategic pitches. The focus group tools proved to be indispensable in the development of the immersive installation. The team recognized the necessity of involving people in the process, as they could not fully comprehend the user experience until individuals actually engaged with the installation. Designing solely based on assumptions would have been like working in the dark without a clear understanding of how users would interact with the installation. Therefore, the team relied heavily on focus groups to gather valuable feedback and insights from users, enabling them to iteratively refine and enhance the immersive experience.

4.2.5 Ikon - Collio XR

Design process

For the second project by Ikon company, the process also followed a spiral path. However, some peculiar features distinguish it from the previous one because of the inherently different context. The design process began with a "Brainstorming/Concept" phase, with external stakeholders (the commission) interacting with Ikon's CEO, CTO, UX expert, project manager, and storytelling expert. From this point, two parallel processes unfolded: one referring to the design and development of the cultural and historical context, the other to the realisation of the mobile app and AR/VR contents of the experience. The first one has been conducted with less iterations, while the second one has been developed with a deeper iterative approach, due to the complexity of the activities carried on.

The former was characterised by the "Historical research" – with output referring to different historical periods, from the Middle Ages to the Renaissance, to modern times – "Storytelling narrative", in which the information collected in the previous phase are

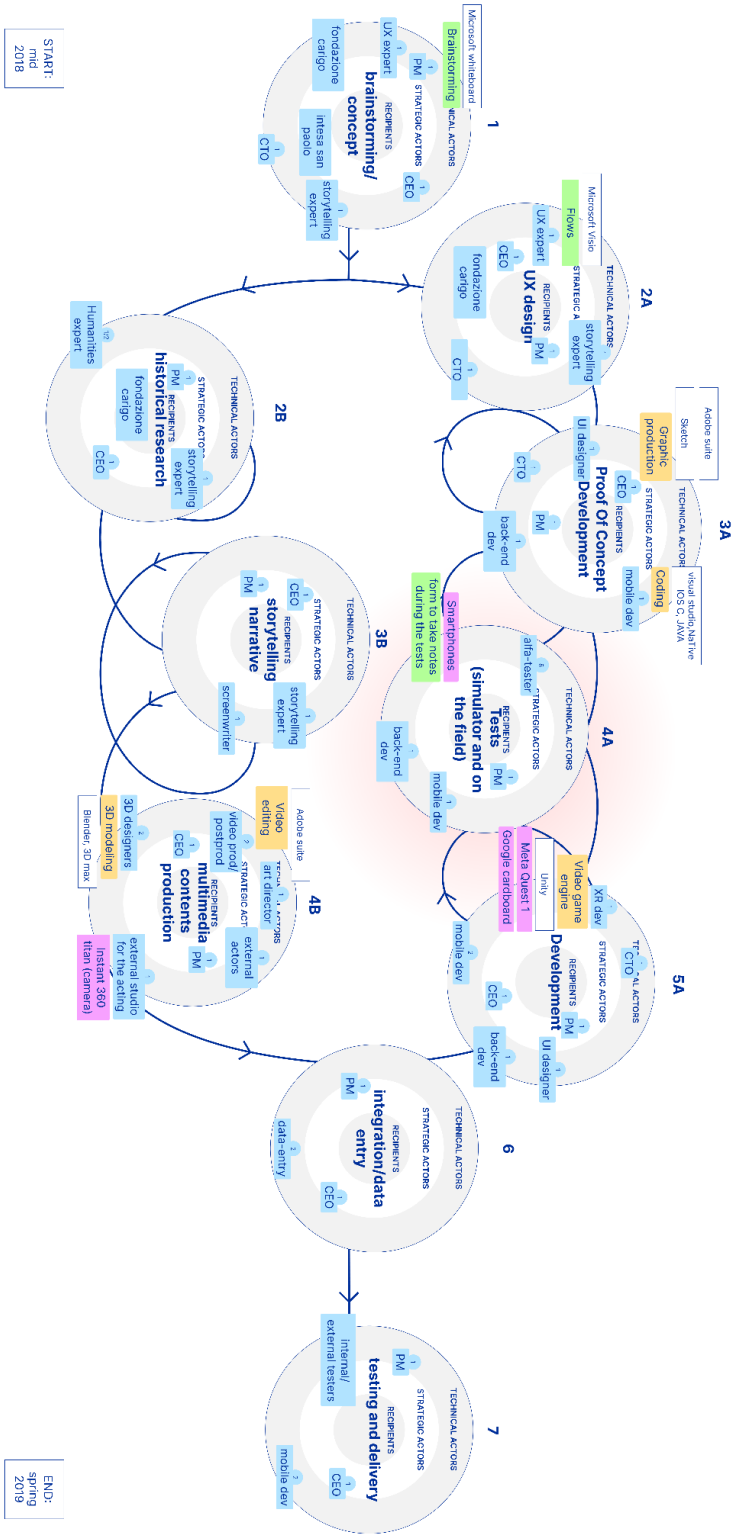


Fig. 36: Schematic representation of the process, phases, actors and technologies and tools of the Collio XR case study.

elaborated into plots with characters and stories, and "Multimedia contents production" phases.

The latter included a "UX design", a "Proof of concept and Development", a "Testing" and a "Development" phase.

The interviewee highlighted the "Testing" phase as a critical aspect of the project, particularly for identifying technical requirements that were not initially specified at the project's outset. As the solution provided was highly complex, it required thorough and repeated testing to ensure its effectiveness. However, carrying out the "Testing" phase encountered difficulties due to the nature of the required activities. All tests had to be conducted by physically walking or riding a bike along the entire paths of the Collio territory. This process demanded significant time and effort to thoroughly assess the functionality and performance of the solution.

Finally, these two parallel processes (Historical and Technical ones) interlaced for the "Integration/Data entry" phase, where the mobile app, VR and AR content had to integrate the historical and cultural content produced. A conclusive iterative "Testing and delivery" phase led to the final outcome of the process.

For the *Collio XR* project, the design process took from half of 2018 to spring 2019. The interviewee affirmed that the overall design process has shown differences with respect to the *normal procedures* of the company because of the unique context the experience was related to. This led to the general consideration of the challenges faced as a value point for future projects, while the "Testing" phase was recognized as a pain point as it needed to be performed in the territory.

Actors involved

Collio XR, firstly involved the stakeholders commissioning the project (through the program *CarigoGreen*, funded by the Carigo Foundation, with Banca Intesa San Paolo), the CEO, the CTO, the project manager, and the storytelling expert from the Ikon company. They sat together to define project needs and requirements. Then, the process is separated into two parts.

On the one side, historical and cultural contents were developed by one or two humanities experts, the storyteller expert, a screenwriter, and actors involved in the voice recording (an external studio was called). Here, also a video producer and postproduction expert were engaged with the art director as well and three 3D designers. On the other, a UX expert followed the first phases of the technical path of the design process, with UI designers, a back-end developer, a mobile application developer, an extended reality developer, and 8 alfa-testers into the "Testing" phase. CEO, CTO, PM and in the first phases also external stakeholders followed these two parallel processes. Two data-entry professionals were protagonists of the "Integration" phase, in between the content and the technical part of the experience. Ultimately,

for the final "Testing and delivery" people from an external association on culture and sport were recruited for testing.

Technologies and tools

From a technological perspective, *Collio XR* consists of a mobile application with the possibility to enjoy VR, AR and audio content. The mobile app has been developed through coding, UX and game engine software, while the graphic contents were created with programs in the Adobe Creative Cloud Suite. AR and VR content leveraged a video game engine, a 3D modelling software and some parts with Insta360 camera for recording 360 video content. In addition to AR and VR technologies, the *Collio XR* mobile app offers a wealth of audio content specifically designed to provide users with an immersive and interactive experience. This content includes stories, tales, and other engaging narratives with references to history and tradition that allow users to enjoy digital content while freely walking and exploring their surroundings. This approach grants users the freedom to move around and observe their environment while still being immersed in captivating and enriching audio narratives.

4.3 Discussion

4.3.1 Processes

Semi-structured interviews proved to be suitable means to gather this kind of articulated information. Indeed, defining design processes was a challenging task, feasible with the support of the researchers and the canvases prepared to guide the conversation.

Overall, it is interesting to observe how the depicted processes generally adhere to the phases described in the Design Thinking one (Dam & Siang, 2021). Firstly described by the Hasso Plattner Institute of Design (known as the d.school) at Stanford, it gradually spread to different domains and it is inherently linked to human-centred, non-linear and iterative ways to design. This last aspect was particularly emphasized in all the interviews.

The spiral representation was the most common. This choice can be attributed to the design challenge itself, dealing with innovative technologies and experiences. Indeed, ideas and results from the application of immersive technologies necessitated multiple rounds of internal testing and validation, as well as the involvement of external actors. Consequently, this iterative model with – apparently – linear phases following one another was selected as the most suitable representation of the design process. Only one of the selected cases, Dataspace, opted for a fully iterative (circular) depiction of the process, but iterations of different kinds emerged in all cases, in relation to the spiral model.

The Design Thinking process traditionally unfolds in five stages ("Empathize, Define, Ideate, Prototype, Test"), which can be carried out in different orders, in parallel, or repeating themselves, as demonstrated by the interviews too.

"Empathize" is the phase concerning research to get a better understanding of the context in which the project is inserted, a fundamental step in all the presented projects. However, human-centricity and user research did not explicitly lead this phase in any of the discussed projects – as it is prescribed in the Design Thinking process. Nonetheless, multiple perspectives and interests are included from this very early stage in all the reported examples. For instance, Ikon Company leveraged a participatory approach, inviting interested stakeholders at the table in which the problem to address was framed, but also Ars Electronica FutureLab and Collective Act had different professional figures involved from the very beginning.

"Define" is a synthesizing step, where all the insights emerging from the preliminary research converge into the framing of the design problem. Undoubtedly it is unavoidable, but it can be more or less explicit. In a couple of cases, *Museo di Monte San Michele* and *DataSpace*, this has been recognized as a distinct phase, respectively called "Define" and "Question/Future vision". In the others, this moment did not gain the same importance in the perspective of the interviewees, who described a more direct transition to the "Ideate" phase.

Indeed, most often, the initial research directly informed the elaboration of ideas and experimentations to define the path to undertake.

In the following stage, where ideas began to be developed, the "Prototype" and "Test" references from the Design Thinking process could be easily perceived in all the examples. Encompassing different facets – from technical and financial feasibility to accurate and effective communication and UX – the experimental nature of projects dealing with immersive technologies prominently emerges and results in a highly iterative process.

Overall, because of the intended flexibility of the Design Thinking process, which reflects the wide range of conditions in which a project might be developed, it is quite easy to find affinities with the analysed case studies. However, an additional stage like "Implement", as suggested by Nielsen Norman Group in their practice-oriented vision (Gibbons, 2016), is needed to complete the process. Indeed, underlying the fact that we are referring to projects that were actually accomplished, a reference to the stage in which they have been deployed recurs in the examples in terms of "Delivery" or "Production", which mark the moment in which the iterations have come to a conclusion.

4.3.2 Actors

Design team & stakeholders

The design processes described in all the interviews generally present a varied range of professional figures.

From the earliest stages, multiple actors are involved, both internal or external to the organisation in charge of the project. In particular, the case studies can be differentiated based on whether they have a commission or not. Both the examples provided by Ikon Company have explicit patrons who were actively engaged in the first definition of the brief, consistently with human-centred design practices, and their opinion was also valued for the final implementation.

Even though the other cases have different origins, for their kick-off, they all share the constant presence of people with decision-making, managerial, and directive responsibilities (e.g. CEOs, project managers, etc.) together with professionals who bring various relevant perspectives to the project.

The cooperation of multiple experts characterises the entire process, bringing richness to the team and allowing the actual materialisation of the project. From technicians to researchers, from marketers to creatives, from managers to testers, a significant number of different disciplinary experts are necessary. Expectedly, technical figures have a prominent role during project development, but what can be observed is the array of specialisations in which they can be distinguished. To deal with immersive technologies the workload should be divided into many specific tasks (programming, 3D modelling, light design, sound design, etc.) to achieve good results, but what makes technical skills meaningful is the interaction with scientific experts, researchers, and creatives of various kinds who can bring interesting positionalities to the experience for which they are designing. Indeed, it can be noted that the more ambitious the immersive experience, the more multidisciplinary the design teams were.

Users

Generally, the analysed case studies did not have a specific target audience beyond the interest in the content, purposes and modalities proposed by the experience itself. The immersive solutions were meant to be accessible and suitable to users of various genders, ages, cultures, educational backgrounds, languages, and physical attributes, and the people attracted by the different experiences varied only for situated features

OVRDark appeals to users who are interested or used to HMDs(Playstation VR) and immersive horror video games; *Dataspace* is an immersive installation for people who are willing to look into media data for acquiring a different perspective through novel

visualisation and interaction modalities; *the Dreamachine* attracts visitors who are curious to make new experimental experiences related to mental processes; while *Museo di Monte San Michele* and *Collio XR* are case studies enjoyable by users interested in exploring the overlapping layers of information that valorise the cultural heritage of the territory.

Overall, no distinctive pattern can be recognized in the target audience of immersive experiences. Therefore, while they can potentially reach anybody, they address to specific categories of people based on the distinctive aim they tend to fulfil.

4.3.3 Technologies and tools

The primary technological categories identified within the analysed case studies include Virtual Reality, Augmented Reality, projection, as well as light and sound systems.

VR, AR and projections are used to enhance ordinary experiences into extraordinary ones, giving the users new ways of approaching the installations' contents. However, it was demonstrated that even seemingly traditional technologies, like light systems, might be used to design totally new experiences in terms of users' immersion, as in the case of *The Dreamachine*. What marks a distinction with respect to the other case studies is the intentionally uncharted experimentation that required the involvement of diverse professionals.

Talking about the tools used to convey the immersive experiences, 3D modelling, 3D rendering, 3D animation and game engineering are a constant presence in the case studies, demonstrating the trends that attract the attention for developing strategic technical skills to digital environments and the adoption of AR, VR and animated contents for projections overlapping the tangible world.

4.3.4 Limitations and overall findings

In the wide-ranging panorama of immersive experiences and technologies, it is patent that the analysed case studies cannot be statistically representative or exceptionally significant for generalizations. Acknowledging the limitations in number, collection, and selection modalities, as well as the situatedness of the projects investigated, the analysis of the interview results has yielded intriguing insights regarding various case studies on immersive experiences and installations. A recurring theme among these case studies is the employment of immersive technologies to transform a conventional experience into an extraordinary one. The realm of video games particularly emphasizes engagement as a pivotal characteristic, and the incorporation of Virtual Reality further amplifies the level of user immersion. Dataspace presents an interesting case as well, employing immersive environments to enhance the process of connecting users with media data, thereby augmenting routine activities such as reading the news and acquiring information. Similarly, *Collio XR* and

Museo di Monte San Michele utilise immersive technologies like Virtual and Augmented Reality to provide an enriched landscape experience and cultural engagement. These case studies are noteworthy as they demonstrate that the quality of immersive products for users is not solely dependent on head-mounted displays or smartphones; rather, various elements such as emotionally engaging content, overall user experience, meticulous details in video and animation design, and production intricacies all contribute significantly to the final immersive product delivered to users. Generally speaking, the questionnaire-based research has further highlighted the impact of immersive technologies on enhancing artistic, entertainment, cultural, and other types of experiences.

Overall, considering various perspectives such as stakeholders and professionals involved, technology and tool clusters utilised, diverse target audiences, and fields of application, it is evident that interdisciplinarity is a significant factor among the analysed case studies.

In regard to the design processes, it can be noted that the presented examples, albeit with some variations, adhere to a design-oriented methodology. This methodology typically involves several phases, including a preliminary research phase, followed by concept generation and validation phases, and culminating in the development and delivery phases. If applicable, the involvement of a commission or other external stakeholders occurs primarily during the initial and final stages of the processes. What remains consistent across all case studies is the iterative nature recognized within each individual phase. Interviewees have confirmed that the incorporation of immersive technologies introduces a multitude of attempts and experiments throughout the project, sometimes employing novel methodologies or activities to achieve the desired outcomes. In the field, depending on the specific expertise of the creative team regarding immersive technology or the application domain, these companies, studios, and creatives are actively exploring and pioneering the development of new design methodologies for immersive experiences and installations.

The interview results highlight the remarkable interdisciplinarity among actors and stakeholders, depending on the project's objectives, technologies and desired outcomes. From CEOs to researchers, designers to developers, and historical experts to technical specialists, a diverse range of expertise is harnessed. An intuitable pattern can be traced back to the fact that the richer the design and development team, the more diverse and original the immersive experience can be.

The actors, professional figures, and stakeholders involved mostly depend on the project's field and the technology group engaged. At a strategic level, key actors such as the CEO, Creative Director, or Art Director are consistently present, often accompanied by individuals in roles such as CTO or Project Manager, who oversee the project across all phases. Research and technical teams participate in the related phases, with their expertise varying based on the desired output. For instance, scientific researchers may be involved in projects like *the Dreamachine*, while

historical experts may contribute to cases such as *Collio XR* and *Museo di Monte San Michele*. Other times UX designers and developers, or game engine developers, or 3D artists or other technical roles are present, depending on the technological output needed. This reliance on technological outcomes and application domains also becomes evident in the analysis of interaction modalities. For instance, the user experience in *Collio XR* significantly differs from that of the *OVRDark* video game due to variations in VR tools used. In one case, the experience takes place and enhances the immersion in an open space landscape location, with a mobile app and site-specific content. In the other case, users engage in a horror-themed escape room-like video game utilising head-mounted display (HMD) tools and can have a consistent experience wherever they are physically located. Particularly unique in this regard is *the Dreamachine*, which introduces singular technology and tools into the experience itself.

Regarding the different experiences, Virtual Reality emerges as a prevalent element across several case studies, often complemented by other immersive technologies and tools such as audio systems and Augmented Reality. Each case study, in general, provides intriguing insights into the design process and the experiential characteristics associated with its specific technology, tools, and contextual factors. However these don't necessarily imply a specific target audience, which differentiates only based on interest toward the contents and typology of experiences themselves, and can potentially encompass a wide-ranging public consisting of various genders, ages, educational backgrounds, and social characteristics.

5 Future Backcasting

5.1 Introduction and methodology of the workshop

The conclusive activity of the research project object of this report entails a time and imagination leap to envision how a preferable future of immersive experiences would be to confirm or negate whether the analysed current tendencies are actually destined to lead us to flourishing scenarios in the investigated domain or different or new paths should instead be undertaken.

Drawing on the analysis of the gathered materials, the research team arranged a Future Backcasting workshop session. The workshop included the involvement of multiple stakeholders within the European consortium, alongside artists, designers, and creatives engaged in immersive experiences and installations. The selection of participants was based on their affiliation with the previously investigated case studies and connections established by the research group. The workshop consisted of a total of nine participants.

To be easily accessible to all the contacted and available people, it took place online, in English and it was recorded and transcribed for in-depth examination.

Future backcasting is a method providing an overview of one or more hypothetical future scenarios and works backwards to identify the steps needed to connect that specified future to the present, represented by personas, a service, or a system (Future Backcasting | Service Design Tools, n.d.).

The primary objective of the workshop session was to envision a near future scenario, set in 2049, specifically for the artistic and cultural domain.

Following the scenario construction phase, the session then shifted its focus to discussing the design process associated with the constructed scenario. This includes considerations related to actors, skills, and tools required for its realisation.

To facilitate the workshop, the structure and materials were organised using Miro (https://miro.com) boards, allowing participants to access and contribute to them in real-time using their personal devices. Simultaneously, the participants were connected through Microsoft Teams, with the session divided into two separate rooms to enable them work in two different groups. In preparation for the workshop, all participants were invited via email and requested to confirm their attendance by completing individual cards in a Miro file (Fig. 37).

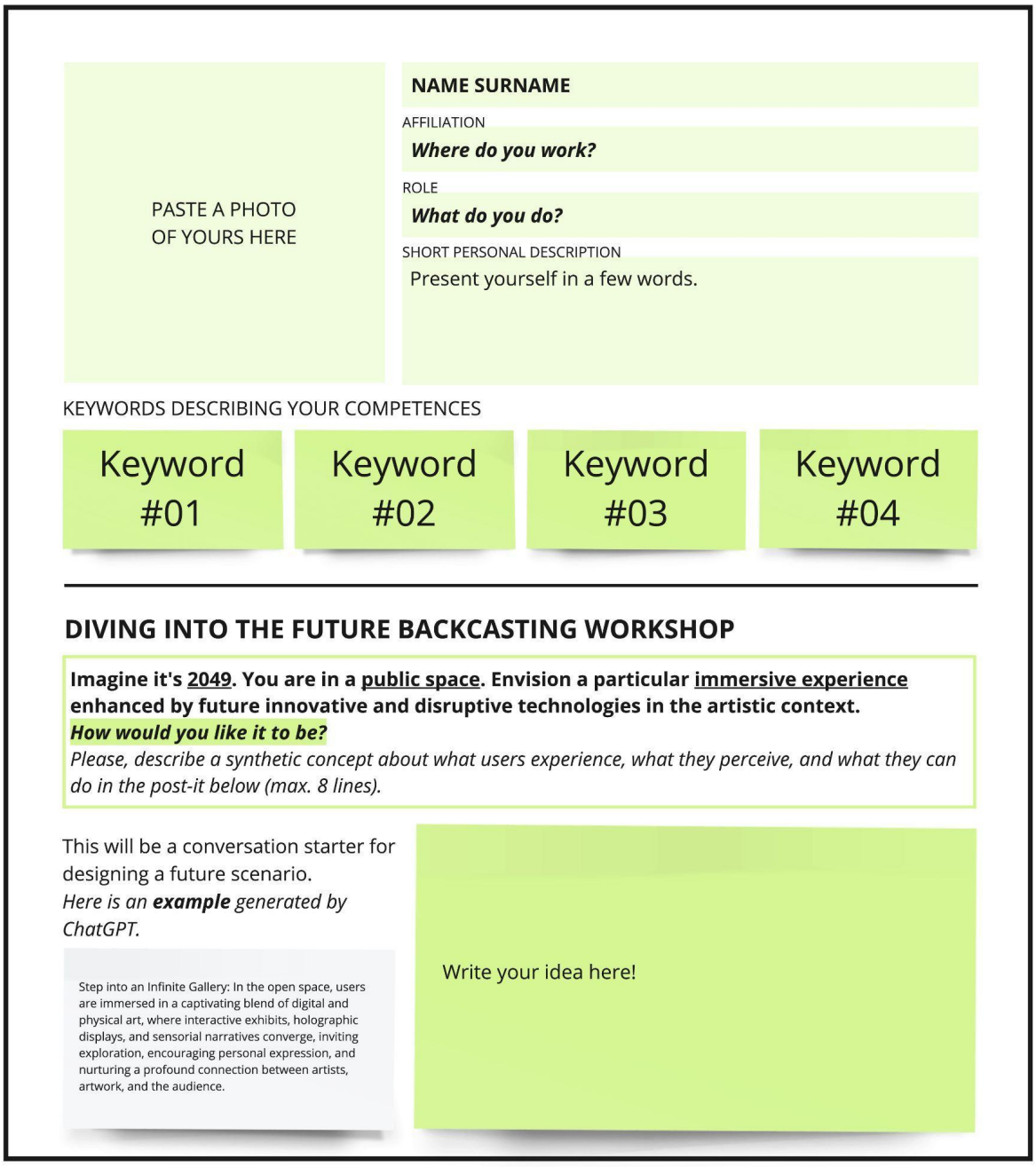


Fig. 37: Blank individual card given to the workshop participants in order to collect general information and a first envisioning input.

The card worked as an introduction of the participant to the others, a collector of personal information of the participants for the research group, and as the first step into the activity of the workshop. It includes the possibility to upload a personal photo into a box; then, the indication of the participant's name, surname, affiliation, role within this entity, and a short personal description. Four keywords have been asked to finally synthesize the previous information.

The second part of the card is related to the first step asked the participants about the activity. A brief is given: "*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.*" The year chosen is 2049 in order to give the participants a temporal distance not too far but enough to imagine new technological possibilities in the field.

The location given is a public space to follow the objectives of the European project that focus on this kind of space. An artistic context is required, while the overall research is constructed on the exploration of this field. The participants are asked to describe a synthetic concept about what users experience, what they perceive, and what they can do: the scenario has to be described in the post it given in the lower part of the card, in a maximum space of 8 lines.

Given the provided scenario, the research team proceeded to consolidate all the individual answers onto a new Miro board. Each participant had access to all post-its placed in front of them.

After an initial twenty-minute general introduction, the participants were divided into two Microsoft Teams rooms to facilitate discussions on their ideas. This phase of the workshop session focuses on scenario construction and was supported by an initial part of the Miro board, as shown in Fig. 38. The research team moderates a discussion among the participants to arrive at a shared scenario idea. This activity spans approximately 25 minutes, beginning with the moderator explaining the ideas from each participant, followed by group discussions to refine a shared scenario idea.

Throughout the session, the research team ensures the timing is managed and provides guidance to the participants.

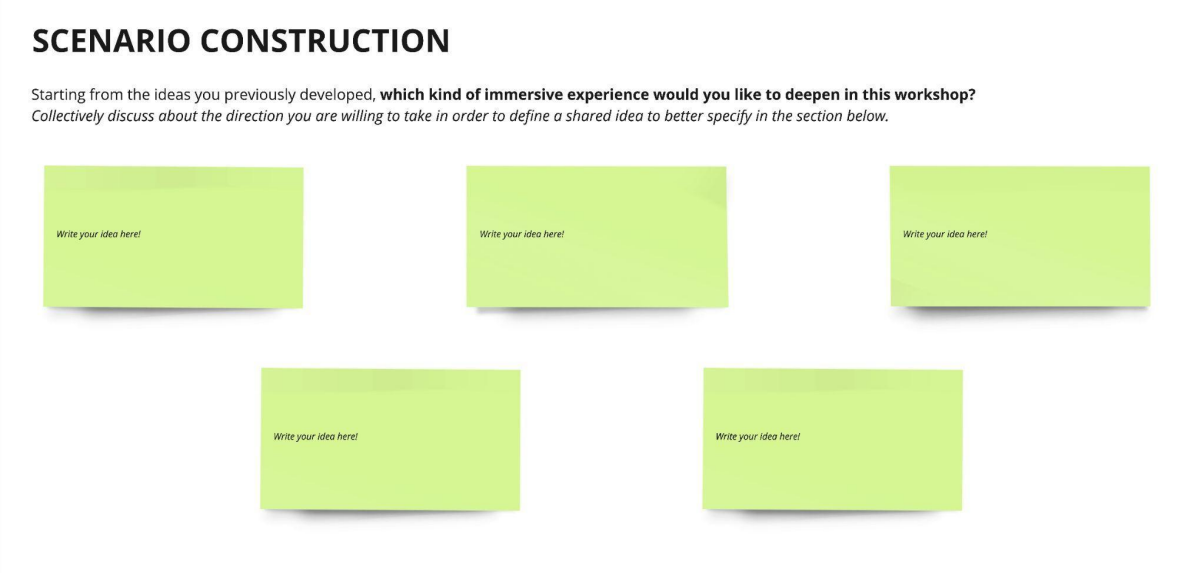


Fig. 38: Miro board part dedicated to the introduction of scenario previously created by each participant, to foster a common scenario construction.

The second part of the session involved the participants recording the items discussed, lasting for about 15-20 minutes. Several questions are posed to help the group provide clear answers that contribute to a better definition of the future scenario (Fig. 39).

The first set of questions pertains to the context of the experience, including the location and temporal specifications. Subsequently, participants were prompted to describe the environment in which the user is immersed and the user journey within the overall user experience. Additionally, two questions were posed concerning interaction touchpoints and the appearance of tools and technologies.

Fig. 39: Second step of the scenario construction in which specific questions support the definition of details related to the envisioned immersive experience.

The third part of the board referred to the building of the scenario: once an idea was fixed, the participants were guided toward the identification of a *dream-team* (Fig. 40) for the building of the scenario itself. This activity tries to answer the questions:

- Which kind of professionals are necessary to design the imagined immersive experience scenario?
- What would be their roles?
- Which kind of competencies do they need?

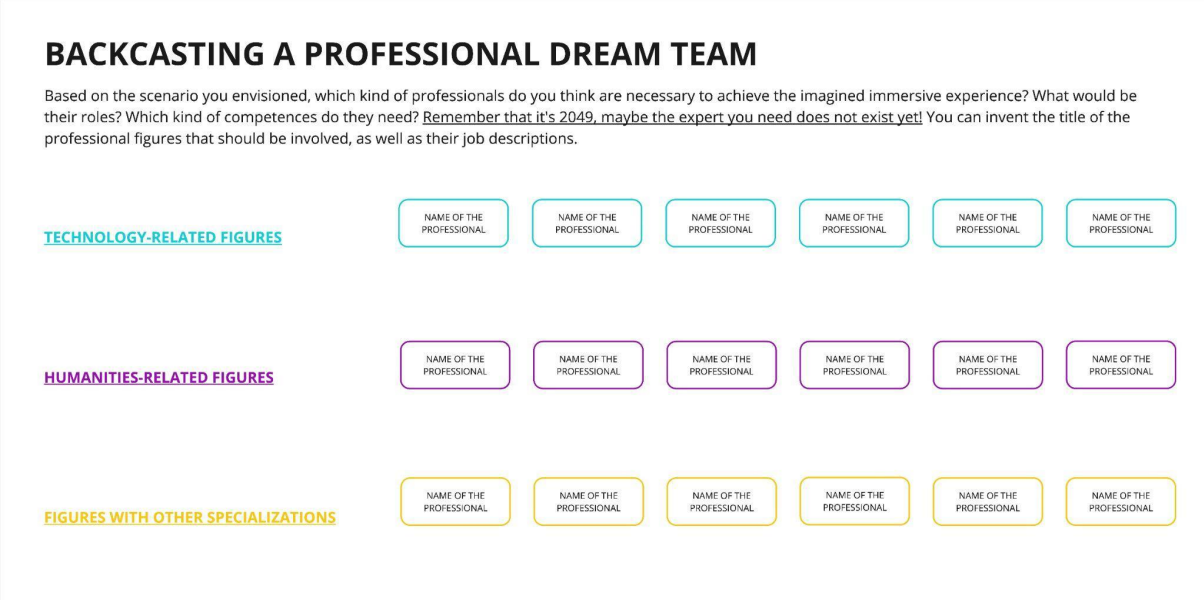


Fig. 40: Miro board part dedicated to the creation of a professional dream team to support the envisioned future scenario.

During the workshop session, participants were encouraged to unleash their imagination and envision new types of 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 prepared boxes labelled *Suggestions from the present* which contained information about current state-of-the-art immersive technologies, tools, and interaction modalities to support the scenario construction. In addition, a further box had been provided to offer suggestions about the generic skills of professionals typically involved in the design of immersive experiences and installations.

Participants were free to use these boxes, shown in Fig. 41, to inspire their creativity and identify new immersive experiences and appropriate professional figures for the previously constructed near-future scenario.

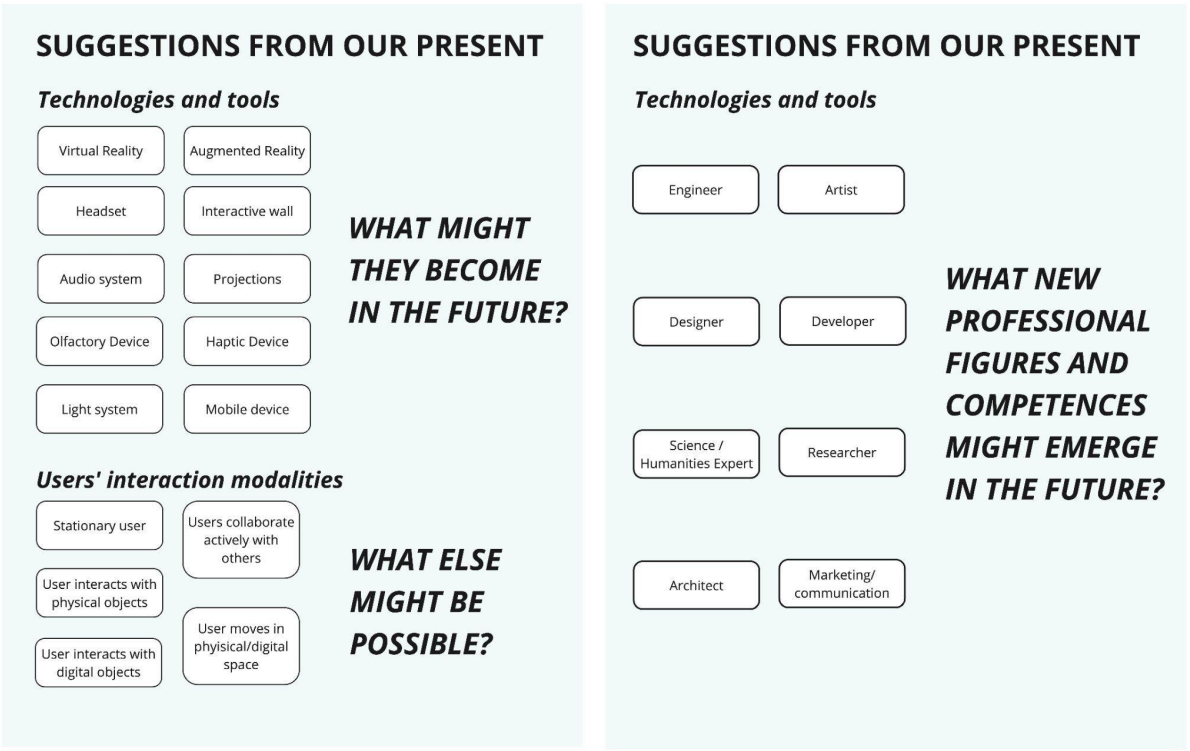


Fig. 41: Two boxes of Suggestions from the present, offered to participants as support in the construction of the future scenario immersive experience and the related dread team.

The discussion surrounding actors, roles, and skills could be addressed in the fourth and final part of the board. In this last section, the title and description of the experience were copied and pasted, serving as a focal point for participants to engage in the final discussion. It was created to provide restitution of the envisioned scenario and dream team. The moderator assisted in placing the relevant figures onto the board, aligning them with the requirements of the envisioned scenario. After this activity, the two groups reunited in the general Microsoft Teams room, to discuss the envisioned scenarios, supported by the material produced in the last section.

5.2 Results

The overall workshop session lasted 2 hours: it started at 13:00 CET on Friday the 23rd of June and it finished at 15:00.

The participants included: researchers Chuan Li and Guillem Bacete from C-LINK, professional Natalie Sarkic Todd from the Battleground, researchers Tim Schneider and Xavier Maitre from UP-Saclay, project manager Beatrice Sangregorio from Fondazione Politecnico di Milano, creatives Matteo Tora Cellini and Marco Barsottini

from camerAnebbia studio, CEO and Creative Director of IKON company Enrico Degrassi, who was not present in the call but enriched the discussion giving his idea for the scenario.

After the introduction given by the research team, the participants were split into two break-out groups: Bacete, Maitre, Sangregorio and Cellini on one side and Chuan, Todd, Schneider and Barsottini on the other. The research team also split into two separate moderation teams. The two groups were created following the participants' skills and roles and the ideas they had generated in the given charts.

The overall session followed the time indication designed, and the two groups generated interesting scenarios with different characteristics.

5.2.1 First future scenario: A' la cARTe. Day-by-day seamless and unconstrained art immersion.

The first scenario generated is called *À la cARTe*: it is set into open accessible public spaces big enough to allow users to interact with each other.

The envisioned scenario revolves around the utilisation of ultra-thin devices, such as contact lenses, enabling users to engage in immersive hybrid experiences facilitated by brain interfaces and body implants. These experiences can seamlessly integrate into users' everyday lives, allowing them to control and disengage from the experience at any moment. Users also have the option to share their experiences with others or explore the experiences of fellow users.

Technology and tools

The scenario introduces very thin and light wearable devices users wear into their everyday routine. Additionally, brain and body implants are considered in these wearable systems. These devices let the users live very high-definition immersive artistic experiences without the visible layer of the tools, living a smooth and seamless experience.

Users and interaction modalities

In the envisioned scenario, the environment in which the user is immersed is a hybrid one, blurring the boundaries between the virtual and tangible worlds. Users have the ability to control the immersiveness provided by the artificial content. The participants imagined an augmented reality interface that can be controlled through the brain implants mentioned earlier. This interface serves as a shared platform for different users present in the tangible space, allowing them to interact with each other. However, access to individual experiences must be granted before sharing can occur. Users

have the freedom to access different experiences or voluntarily disengage from the ongoing one.

The system leverages all physical senses to provide a rich sensory experience. Additionally, it incorporates other elements such as monitoring the user's heart rate, brain activity, and emotional engagement to enhance the overall immersion.

Professionals

Generally, it could be said that there is no prevalence between technology-related figures, humanities-related and hybrid ones in the roles imagined during the scenario. The workshop participants envisioned several roles that do not currently exist or are in the early stages of development. One key area identified is the expertise in sensory experiences, with specialised roles such as sound designers, smell designers, touch designers, and their corresponding developers. Collectively, these designers are referred to as *ambient designers* and are considered hybrid roles that bridge various sensory modalities.

From a technical perspective, the team identified the need for developers working on the design outputs given, as well as a *senses expert* who possesses in-depth knowledge of sensory perception. Additionally, the presence of an AI developer is envisioned, potentially specifying the role of a software developer, as the scenario includes an AI agent guiding the user flow within the experience.

To address the brain implant aspect of the device, the team identified the roles of a brain interface specialist, a brain engineer, and an implant expert. These individuals would contribute to the design and development of the brain implant technology.

In terms of understanding human behaviour and psychology, the team recognized the importance of having a sociologist or psychologist, as well as a neuroscientist, working alongside artists and creators to shape the artistic experience. Furthermore, an immersive consultant and an ethics expert (Stuckelberger, 2018) would provide valuable insights and guidance throughout the overall design process, ensuring ethical considerations and users' well-being are considered.

Alongside the new and emerging competencies, there will still be a presence of *traditional* roles that remain relevant in the future scenario design process. The project manager will continue to guide the overall process and coordinate the activities of the different professionals involved.

From a design perspective, roles such as UX (User Experience) and UI (User Interface) designers, 3D designers, and graphic and communication designers will contribute their expertise to the team. They will be accompanied by a communication expert who will support effective communication strategies.

Content creators and content providers will play a crucial role in the creative aspects of the immersive experience. Their contributions will help shape the content and artistic elements of the scenario.

Developers and specific engineering roles, including electrical engineers, will form the development team responsible for implementing the technical aspects of the experience. The analysis of various data generated by the experience will be undertaken by a data scientist. This role will contribute valuable insights derived from data analysis, aiding in further refining, and enhancing the immersive experience.

Starting from the final output of the workshop, consisting of the title and description, the research team decided to adopt Midjourney (https://www.midjourney.com/app/) to create a visual restitution of the envisioned scenario. In addition, the envisioned dream team has been used to complete the visual representation, shown in Fig. 42.

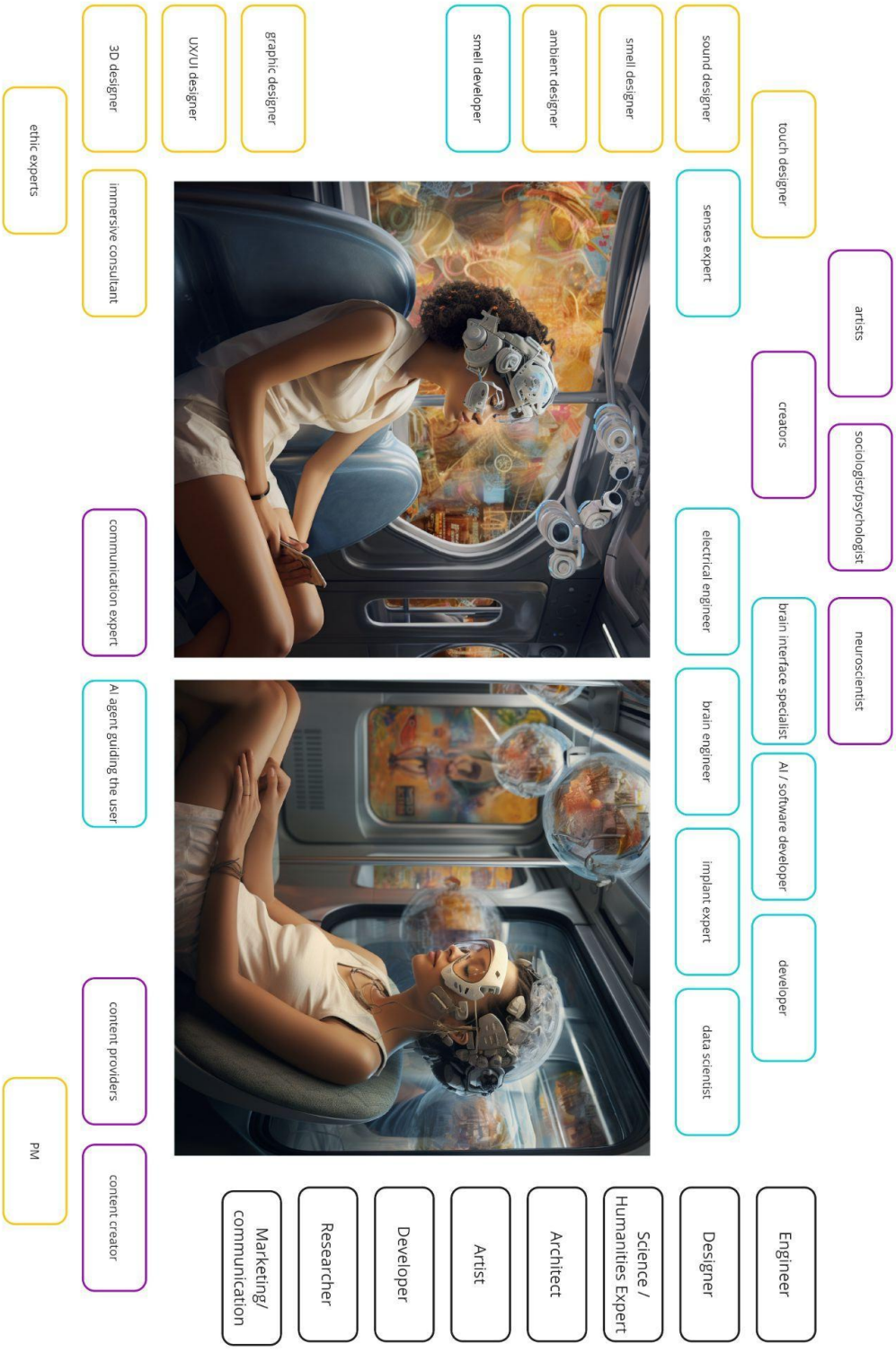


Fig. 42: Visual restitution of the first envisioned scenario and the related dream team.

5.2.2 Second future scenario: Human shared reality in a connected world, with a device-less experience

The second scenario is envisioned in museums or morphological spaces that facilitate connections between individuals present in the tangible environment and others who are not physically present. This hybrid environment is characterised by the presence of images, holograms, and avatars. The experience in this scenario involves linking different locations within various museums and utilising digital archives to enable this connectivity.

Technology and tools

The envisioned scenario involves using Artificial Intelligence to control holograms and various technologies within the museum or building itself. This includes transformative architectural technologies that can change the properties of materials, such as transitioning from solid to fluid iron. Additionally, molecular technology, such as OLED floating transparent screens, is utilised to enhance the visual experience. Furthermore, localized sound sources or sound bubbles contribute to an immersive audio experience. Notably, the team has conceptualised a device-less experience, where visitors do not require physical devices to interact with the immersive elements of the scenario.

Users and interaction modalities

In this imagined scenario, users have the freedom to navigate and move within the virtual space, just as they would in the physical environment. They can interact with avatars and elements that are projected as holograms. Furthermore, users can engage in collaborative experiences and interact with each other within the virtual environment. When approaching a hologram avatar, users can initiate discussions and ask questions, and the avatar, functioning as an expert guide on the given topic, responds and interacts with users as if it was a real person. The avatar's behaviours are controlled by AI systems, enabling it to react realistically to users' emotions and queries. These 3D hologram avatars serve as digital touchpoints within the user experience. Additionally, the experience itself encourages and promotes collaboration between users, fostering a sense of shared engagement within the advanced hologram system.

Professionals

During the workshop session, the participants emphasized the significant role of the AI system within the overall immersive experience. The dream team for the experience

design process includes roles such as AI developer, responsible for creating and implementing the intelligent algorithms that power the interactive elements of the experience. The AI expert provides expertise in designing and optimising the AI system to ensure seamless integration with the immersive environment.

Moreover, AI emerges as an entity with self-programming capabilities, continuously learning and adapting to user interactions, enhancing the overall user experience. The system acts as a guide, offering personalised recommendations and responses based on user preferences and emotional cues.

Within the creative team, key roles comprise the artist, who creates the overall immersive experience concept; the curator, who plays a pivotal role in selecting and arranging the digital artefacts and exhibits, creating a cohesive narrative that engages and educates the users.

Working closely with them, the artistic director provides guidance and oversight throughout the entire creative process, and ensures the alignment of the immersive experience with the intended artistic and cultural goals.

To ensure the accuracy and integrity of the shared content, the creative team may collaborate with anthropologists and archaeological experts. Their knowledge and expertise contribute to the authentic representation of cultural heritage and historical artefacts, enriching the immersive experience with valuable insights and context. Additionally, a scientific committee may be established to provide supervision and guidance, ensuring the accuracy of scientific information presented within the immersive environment.

As for the previous scenario, starting from the title and description, the research team decided to adopt Midjourney (https://www.midjourney.com/app/) to create a visual restitution of the envisioned scenario. A comprehensive visual representation is offered in Fig. 43.

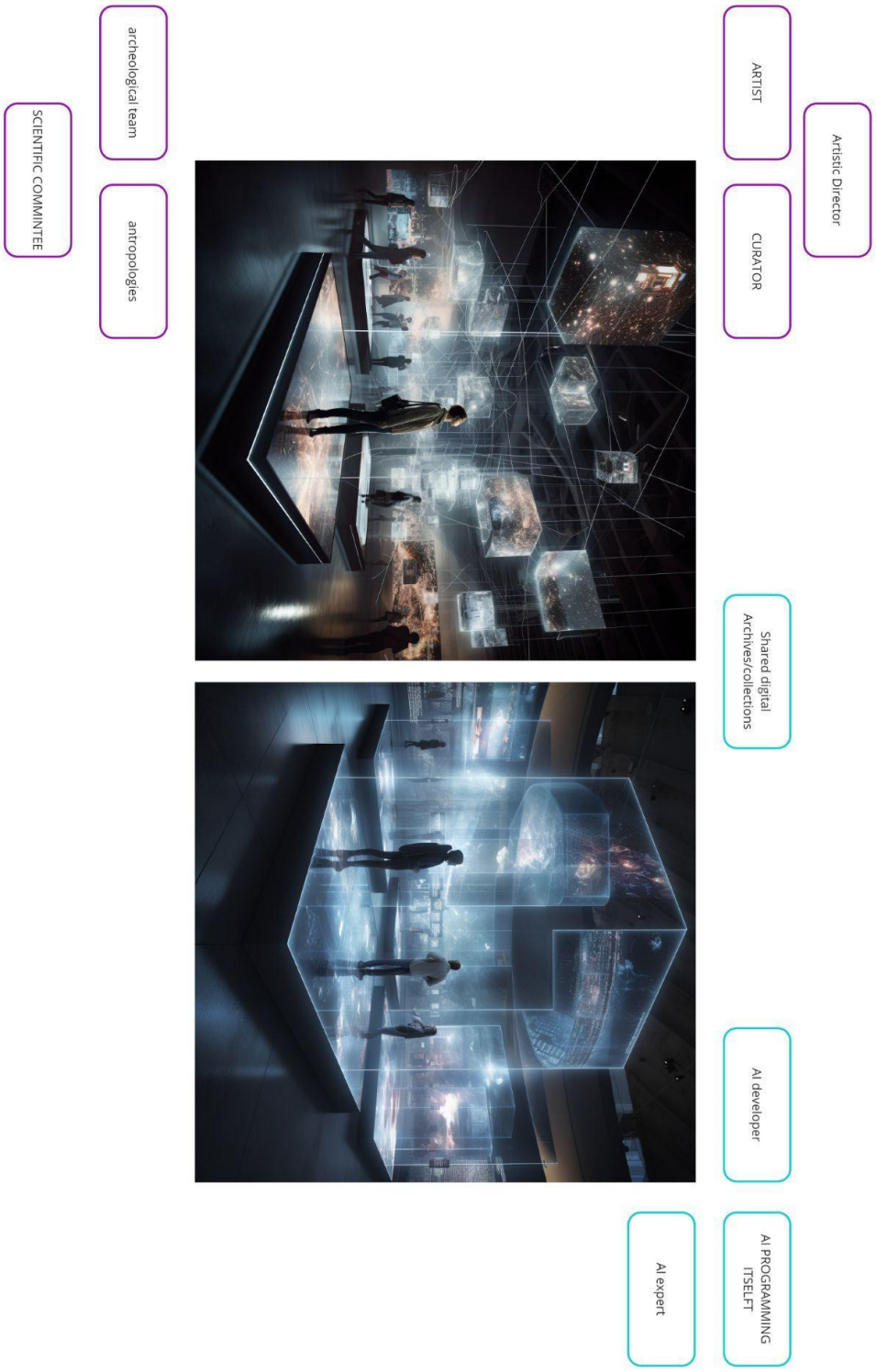


Fig. 43: Visual restitution of the second envisioned scenario and the related dream team.

Furthermore, the research team has identified additional roles that complement the ones generated during the workshop session. Moreover, for the generation of holograms and the creation of avatars and other digital elements, a crucial role is that of a hologram developer. This technical expert is responsible for managing the development process of the projected elements, ensuring their seamless integration into the immersive environment. Working closely with the hologram developer, 3D artists and designers with expertise in 3D animation contribute their skills to bring the digital content to life, crafting visually captivating and realistic holographic representations.

In some cases, the 3D content may be derived from real-world objects or artefacts. In such scenarios, the presence of a 3D scanning expert becomes essential.

5.3 Discussion

In both scenarios, we are presented with intriguing perspectives on immersive experiences in the near future. One notable common aspect between these experiences is the desire to achieve a high degree of seamless immersion, eliminating the perceptible barrier between users and the virtual environment, thus, materialising the Weiser's vision of invisible interface and ubiquitous computing (1993, 1994). The envisioned technology in this near future aims to be minimalistic and unobtrusive, with devices that are as thin as possible or even absent in the second scenario. Gradually, the boundary between the tangible and virtual worlds will fade, allowing users to engage in immersive experiences without the noticeable presence of technology.

In the first scenario, users are provided with a technology that seamlessly integrates into their daily routines, enabling them to control the immersiveness through discreet devices such as contact lenses that function as head-mounted displays. Users possess various levels of control, allowing them to choose whether to engage in the immersive experience, share their experiences with others, or pause their participation, among other options. This immersive experience relies on brain interfaces connected to bodily implants, enabling the capture of human senses and biometric feedback. By comprehending the users' emotional states and augmenting reality with appropriate tools and technologies, a smooth and hybrid experience is achieved.

The second scenario, on the other hand, envisions a seamless experience that relates technology to the physical location itself. Holograms of avatars and objects interact with users, projected within the space. In this case, artificial intelligence serves as the controlling agent of the experience, engaging in dialogue with visitors and curating their journey for an optimal encounter. The installation is deviceless, and the boundary between the tangible and virtual worlds is barely distinguishable due to the projections. Additionally, this scenario emphasizes connectivity, as it facilitates

interconnections between multiple museums and artistic spaces worldwide, enabling the exchange of libraries and curated lists of immersive experiences.

These scenarios provide captivating glimpses into a future where technology seamlessly integrates with our surroundings, granting users the ability to engage in immersive experiences without the encumbrance of conventional devices. By striving for minimalistic and imperceptible interfaces, the boundaries between real and virtual realms are transcended, offering users a fluid and interconnected experiential landscape.

The concept of immersion here involves the suspension of disbelief, where individuals become fully engrossed in the sensory and cognitive aspects of the experience, often to the point where the boundaries between the real and virtual worlds become blurred. Based on the two built scenarios, the concept of immersion can be related to the state or quality of being deeply engaged or absorbed in an experience, environment, or virtual world. The goal is to create a seamless and captivating environment that reaches users' attention, triggers emotional responses, and transports them to alternate realities or heightened states of engagement.

In summary, immersion encompasses the state of complete absorption and involvement in an experience, blurring the boundaries between the real and virtual worlds, and creating a compelling and transformative sensory and cognitive engagement.

In analysing the outcomes of the workshop session, it is noteworthy to examine the identified roles, both existing and new, that will be involved in the design processes of future immersive experiences. Regarding the roles that will endure over time, there have been no disruptive changes from a strategic perspective, as project managers and artistic directors will continue to serve as key strategic and managerial figures. From a design team standpoint, essential roles such as 3D artists and designers, responsible for creating the three-dimensional elements and avatars essential to the immersive experience, will persist. Additionally, the presence of a UX designer to ensure a cohesive overall experience and UI/graphic/communication designers will be required. The creative aspect of the installation experience will be fulfilled by artists. Furthermore, developers and engineers will remain integral to the team, responsible for executing the production and development phases of the design process.

The advanced technological level envisioned in these scenarios will introduce new roles. To delve into various aspects of human psychology and emotions within the experience, content implementation will require the involvement of neuroscientists, psychologists, and experts from humanities and scientific domains, which is already observed in the contemporary art field. Additionally, communication experts and content creators/providers will be necessary in the technical field. As AI tools become increasingly prominent, dedicated AI expert teams will be crucial. Both scenarios incorporate an AI agent that partially or fully controls and guides the experience. The emphasis on engaging all human senses within the immersive environment will

necessitate the presence of specialised roles such as smell designers, touch designers, taste designers, and others collectively referred to as *ambient designers*. Naturally, these design roles will also require the involvement of developers. Senses experts will play a vital role in constructing immersive installations. In the first scenario, there is an added need for brain interface experts, to introduce new UX skills specific to the experience. Given the complexity of the installation, the presence of an ethics expert and an immersive consultant will also be essential.

In summary, the workshop session identified a combination of enduring roles and newly emerging roles, encompassing strategic, managerial, design, technical, scientific, and ethical expertise. These roles reflect the evolving landscape of immersive experience design, adapting to advancements in technology and the multidimensional nature of human perception and engagement.

5.3.1 Possible trajectories

The rapid advancement of artificial intelligence technology suggests a future where AI will play a significant role in user interactions. Even today, preliminary roles associated with the adoption of AI are emerging. This field of technology is anticipated to undergo extensive development, profoundly impacting our daily routines and user experiences with technological devices.

The concept of a deviceless experience, observed in both scenarios, can be attributed to two main factors. Firstly, the continual miniaturisation of devices allows them to become thin layers between our senses and the surrounding environment. Consequently, this enables the augmentation of our surroundings with virtual items and interposed environments. Secondly, advancements in projection technology strive towards achieving highly realistic avatars and holographic items within tangible spaces. The augmentation of tangible reality occurs through the superimposition of projections from external devices, leading to immersive experiences in augmented-hybrid environments.

The progression of sensory technology will contribute to a more accurate reading of human senses, facilitating easier integration with immersive technology devices. This progress is also crucial for the development of brain implants and brain interface controls. Advancements in this field will allow the utilisation of brain implants or body implants equipped with biometric sensors, enabling the monitoring of human physiological conditions for controlling technological devices. To ensure a positive and functional user experience within these everyday devices, expertise in brain interface experience design is required. New roles will emerge to guide the design process, focusing on creating enjoyable and functional experiences with new paradigms.

In terms of interdisciplinary roles related to the artistic production aspect of these experiences, various subjects are already accompanying the field of art.

Neuroscience, psychology, social studies, as well as humanities and scientific experts, are actively involved in the design process of these immersive experiences. Looking towards the future, artistic experiences will increasingly intersect with these fields, fostering deeper connections and collaborations.

Overall, the ongoing development of AI technology, advancements in sensory technology, and the integration of interdisciplinary expertise underscore the evolving nature of immersive experiences. These developments pave the way for transformative and enriched user experiences, bridging the gap between technology and art, and embracing a multidisciplinary approach.

6 Discussion

With the purpose of gaining a comprehensive understanding of the concept of immersion and immersive experiences (both from a theoretical and practical perspective) the research investigated how these can be defined, characterised, and implemented through the application of immersive technologies and considering multiple disciplinary contexts and expertise.

Four main research questions guided the study, encompassing theoretical synthesis, practical understanding, and speculation to identify valuable opportunities for the development of the Artcast 4D project.

Specifically, in response to RQ1 – *How does the scientific literature define the concept of immersion enhanced by digital technologies?* – a systematic literature review guided the research team toward formulating a definition of the concept of immersion. This draws upon the identified characteristics and distinguishing elements acknowledged by various scholars within the past decade. It emphasizes the criticality of human sensory perception and the stimuli conveyed by the artificial environment surrounding the users, which supplant those from the physical domain. It emerged that users' undivided attention undergoes a complete shift, enabling cognitive, emotional, and physical engagement with the artificial reality in which they are fully immersed. Consequently, immersion was 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*".

From the synthesis work that led to the development of a definition overarching the previous ones encountered in the literature, the research team could identify some recurring and essential traits that characterise immersive experiences: the *Keys of Immersion*. The five *Keys* embody concepts associated with the original definition and

summarise the pivotal attributes contributing to an immersive experience or installation.

These include:

- *Presence*: referring to the subjective sensation of being fully present within the immersive environment.

- *Engagement*: considered a fundamental aspect of the user experience within immersive environments. It can be further categorised into *cognitive engagement*, which involves conscious and intentional focusing, and *emotional engagement*, which operates at a more subconscious level.

- *Sensory involvement*: focusing on the comprehensive sensory feedback and environmental stimuli perceived by the users during the immersive experience.

- *Embodiment*: referring to the extent of user interaction with the immersive environments, the level of possibility to interact she has in it.

- *Isolation* from the tangible environment: pertaining to the perceived detachment or separation from the physical surroundings in relation to the immersive experience being undergone by the user.

These essential components provide a comprehensive framework for understanding and evaluating the immersive experience from a user-centric perspective.

Additionally, an overview of the most common digital technologies currently applied to convey immersive experiences was presented and reported a prominence of Virtual and Augmented reality.

Subsequently, a historical review of the evolution of immersive technologies by field of application and by category complemented RQ1 towards addressing RQ2 – *How are immersive experiences currently conveyed?* To deepen this investigation, a set of 57 practical case studies of immersive installations and experiences, was collected leveraging the expertise of the Artcast 4D consortium members via an online questionnaire. These case studies were then analysed to depict a snapshot of the current application of immersive technologies across different fields. Despite the limitations in retrieving extensive information, interesting observations concerned the technologies and tools adopted as well as some characteristics of the installations and experiences (e.g., duration, interaction modalities, contents, etc.). Moreover, the case studies were evaluated by the research team according to the *Keys of Immersion* to gain an intercoder agreement on the general immersiveness that each example fostered. While these proved effective in assessing how the case studies conveyed a sense of immersion, they could express their best potential in evaluating first-hand experiences.

Overall, this multi-layered analysis highlighted the transformative potential of immersive technologies in augmenting conventional experiences by promoting a higher level of user engagement. In the observed cases, this was more frequently connected to VR and AR and to a limited number of senses (i.e., sight and hearing). Indeed, among the technologies fostering these experiences, Virtual Reality emerges as prominent across multiple case studies, reinforcing a current trend. Often, it is complemented by other immersive technologies and tools, such as audio systems and Augmented Reality. As well, contemporary immersive experiences and installations predominantly focus on providing users with content that can be experienced in a 360-degree manner, enveloping them with panoramic views and surround sound. Thus, the current emphasis lies in enhancing users' visual and auditory aspects of the surrounding environment Moreover, active and interpersonal interaction modalities were rarely included and the field of immersive experiences currently suffers from inadequate interfaces, limited collaboration opportunities, and low-quality interaction elements. These findings particularly underlined some gaps that could pave the way to promising opportunities for the project.

Of course, because of the limited information publicly available, a different and more qualitative approach was followed to get a deeper understanding of the design processes leading to immersive installation and experiences, in response to RQ3 – *How are immersive experiences currently developed?*

Five of the most immersive case studies in the set were selected as of interest for the research. This selection was based on the overall immersiveness score that each case study received in the evaluation according to the *Keys* of Immersion previously performed by the researchers, and choosing the most valuable per technological category. Consequently, representatives of the teams who developed the projects in question were engaged in semi-structured interviews aiming at uncovering the phases, the actors, the specific tools and technologies, as well as the value and pain points of their design process. From the results, it is evident that the design processes employed in these case studies vary, but a common thread is the resemblance to the traditional design process and the iterative nature observed throughout the different phases.

Similarly, the actors involved in these projects. including the possible users, mostly depended on the context of application and related contents proposed, and, secondly, on the technologies employed. Therefore, while immersive experiences can target diverse individuals based on the specific case, they can also interestingly comprehend a vast array of professional figures. Some of them, especially those covering key roles such as CEO, Creative Director, and Art Director, were consistently present. Fundamental were also the research and technical teams, whose profiles and contributions depended on the desired output. They could encompass scientific researchers, history experts, UX designers, or technical developers, among others.

In general, the iterative design processes, the positive contribution of multidisciplinary competencies, and the open scopes and targets characterising these projects demonstrated the ongoing exploration within the field of immersive experiences and installations, possibly leading to continuous evolutions. Indeed, as technology develops, further advancements and refinements in immersive design are expected to shape the future of interactive and immersive experiences.

In this regard and to address RQ4 – *How might immersive experiences evolve in the future in the artistic and cultural fields?* – a foresight activity involving different professionals and disciplinary perspectives was intended to identify possible future trajectories to infer gaps and opportunities in relation to the current situation and trends. These might be an essential part of the forthcoming evolution of the field under investigation. Indeed, the future scenarios envisioned during this conclusive workshop activity denoted a notable shift toward strong interactivity and stressed how expertise from different disciplinary backgrounds might trigger and shape unexpected and meaningful outcomes for many of the involved parties.

Further interesting prospects included the development of increasingly minimalistic or deviceless experiences, where the content surrounding the user is seamlessly integrated with highly interactive elements, and the interface becomes more and more blurred and blended with the physical world. These interactions might be guided by artificial intelligence or brain interfaces, allowing for a more intuitive, natural, and immersive user experience. The ultimate goal for the envisioned future seemed to be the creation of hybrid and seamless experiences that can be unobtrusively integrated into everyday routines or site-specific installations. These experiences might offer high levels of interactivity and collaboration between individuals, while relying on cutting-edge technologies. Furthermore, they should cater to the emotional and physical aspects of the user, providing a holistic and engaging experience.

In conclusion, one can observe that increasingly acknowledging and including different peoples' perspectives, competencies, interests, and interactions within the design processes and final results of immersive experiences might be essential to lead the evolution of this field, opening the path to a new chapter of immersive experiences within and beyond arts and cultural heritage.

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Table of figures

Annex

Case studies tables

This chapter shows descriptive sheets of the case studies collected.

1. VR workshops

Politecnico di Milano

General informations

Politecnico di Milano

2022

Educational

Use of VR inside lessons

General description

The case study I have chosen refers to the development of a workshop inside the VR laboratory of Politecnico di Milano: students had to collaborate inside Horizon Workroom virtual rooms in order to collaborate as they were by remote working. The workshop purpose was to show students VR technology potentialities in terms of remote collaboration.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | **Field** | Lab

Software used: *It depends on the workshop, but they were all VR app*

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: **Yes** | No

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: **Yes** | No

Roles involved

VR experts, professors, students, methodology experts

Case study experience

Tech used: *VR*

Technological set up: *HMD*

If temporary, experience duration: *temporary, 1 day*

Narration: Yes | **No** | Playful elements: **Yes** | No | Selection of users: **Yes** | No

2. MARSS

Politecnico di Milano, Museo Astronomico di Brera

General informations

Museo Astronomico di Brera, Milan (Italy)

2022

Astronomy

Educational

General description

MARSS consists of a digital journey inside the MusAB gallery of instruments that allows different categories of visitors to enjoy the museum exhibition in an engaging and interactive way. Virtual content, images, and audio are presented to the visitor through a mobile Augmented Reality application, divided into clips related to the astronomical tools present inside the museum.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | Field | **Lab**

Software used: *Graphic, UX design, 3D modeling, Video Gaming engine*

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: **Yes** | No

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: Yes | **No**

Roles involved: *Designer, Developer, Museum curator, Communication, Scientific subject expert, Copywriter*

Case study experience

Tech used: *AR*

Technological set up: *mobile*

If temporary, experience duration: *permanent*

Narration: **Yes** | No | Playful elements: Yes | **No** | Selection of users: Yes | **No**

3. Nefertari Tumb

Italy, Rome, Infobyte SpA

General informations

-

1994

Educational

Archeology

General description

Interactive virtual reality re construction of the Nefertary Tomb textured with hires photos, full walkthrough, virtual restoration of plasters thanks to direct user interaction. One user per time, HMD or BOOM, SGI Onyx Reality Engine

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*SGI Open GL and reality engine SGI*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	Yes | **No**
Roles involved	*Designer, Developer, Museum curator, Artist, Engineer, Psychologist, Humanistic subject expert*

Case study experience

Tech used	*VR*
Technological set up	*HMD*
If temporary, experience duration	*temporary, 1 year*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

4. Magnetic Field

Politecnico di Milano

General informations

Italy, Milan, Politecnico di Milano

1994

Science

Educational

General description

Interactive virtual reality immersive experience in the magnetic field, retro projection of the behavior of an electrical particle thrown within a magnetic field. Virtual dashboard enabling different setting of the field and other parameters. Didactic application to ease the understanding of the magnetic field laws in physics

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | Field | **Lab**
Software used	*SGI Open GL, SGI reality engine*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	Yes | **No**
Roles involved	*Designer, Developer, Engineer, Psychologist, Scientific subject expert*

Case study experience

Tech used	*Virtual reality (VR), Projection, Audio system*
Technological set up	*HMD, projectors, audio systems*
If temporary, experience duration	*temporary, 1 month*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

5. CELL - Centre for Experiential Learning

Italy, Padova, QBGROUP

General informations

Padova, QBGROUP

1994

Training

Medicine

General description

This is a set of technologies both interactive graphics and immersive virtual reality to train medical equips to cooperate as a team.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*SGI Open GL and reality engine SGI*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	**Yes** | No

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	Yes | **No**
Roles involved	*Designer, Developer, Communication, Engineer, Researcher, Psychologist, Doctor*

Case study experience

Tech used	*VR , AR, Projection, Audio system, Mobile application, Vibro-tactile systems*
Technological set up	*VR HMD, mobile, Projector, Audio system, Vibro-tactile systems*
If temporary, experience duration	*permanent*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	**Yes** | No

6. Nuii, VR adventure

Nuii - Ice cream company

General informations

Spain

2022

Promotion

Entertainment

General description

This case study responds to the advertising campaign sponsored by Nuii, an ice cream brand, which wanted to carry out a marketing action using Virtual Reality. To do so, an exotic experience was developed, virtually located on the island of Java, where the natural products needed to produce Nuii ice cream are obtained.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | Field | **Lab**
Software used	*Graphic, UX design, 3D modeling, Video Gaming engine*

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	Yes | **No**
Roles involved	*Developer, 3D modelling artist*

Case study experience

Tech used	*VR*
Technological set up	*HMD*
If temporary, experience duration	*temporary*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	**Yes** | No

7. Museo di Monte San Michele — IKON company, Italy, Gorizia

General informations

Museo di Monte s.Michele, Italy, Sagrado

2017

Awareness

Cultural Heritage

General description

The museum offers a truly unique immersive experience thanks to its interactive multimedia tools and contents regarding the events of the Italian-Austrian front that have affected Mount San Michele and the Lower Isonzo front. VR HMD room has been taken in account for the case study analysis.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*see interview results*

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*see interviews result*

Case study experience

Tech used	*VR*
Technological set up	*HMD*
If temporary, experience duration	*permanent*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

8. Collio XR — IKON company, Italy, Collio

General informations

Territorio di Collio, Friuli Venezia Giulia

2018

Awareness

Cultural Heritage

General description

CollioXR, narrative paths in extended reality for sustainable development. Fondazione Carigo and Banca Intesa have chosen IKON as a technological partner for the three-year CariGOGREEN3 project, aimed at promoting social and economic development in the territory of the province of Gorizia.
AR, VR and maps and audio system to let the user feel immerse inside the landscape.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*see interview results*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	Yes | **No**
Roles involved	*see interviews result*

Case study experience

Tech used	*VR, AR, audio systems*
Technological set up	*mobile, cardboard HMD*
If temporary, experience duration	*permanent*

Narration	**Yes** | No	Playful elements	**Yes** | No	Selection of users	Yes | **No**

9. El Roque de los Muchachos Visitor Centre

Visitor Centre la Palma

General informations

La Palma, Canary Islands (Spain)

2021

Education

Cultural Heritage

General description

Through the application of the latest technology, the Visitor Centre is able to bring astronomy to La Palma and its visitors. The Visitor Centre is divided into several rooms equipped with devices and displays where the visitor can explore the universe and observe astronomical phenomena as if they were inside the Astrophysics Observatory of El Roque de los Muchacho through VR to Ipads with AR app, proximity sensors and Hologram stations.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*Graphic , UX design, 3D modeling, 3D animation, render, Video Gaming engine, Coding software*

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Developer, Museum curator, Artist - 3D modelling*

Case study experience

Tech used	*VR, AR, Audio system*
Technological set up	*HMD, iPads*
If temporary, experience duration	*permanent*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

10. Galileo all'Inferno

Norimberg ballet, Studio Azzurro, Milan

General informations

Milan city

2005

Entertainment

Art, performance

General description

This show, inspired by Galileo Galilei, results from the artistic collaboration between the Norimberg Ballet and Studio Azzurro. This narrative combines "body moves" choreographed by Daniela Kurz and Studio Azzuro's changing, interactive projections, with snatches of words by Andrea Balzola and music by Tommaso Leddi.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*3D animation software (Blender, Maya, etc.), ..*

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	Yes | **No**
Roles involved	*Designer, Developer, Artist, Communication, Engineer, Researcher, Scientific subject expert*

Case study experience

Tech used	*AR*
Technological set up	*projectors, audio system*
If temporary, experience duration	*temporary*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

11. MUSME - Museo della Medicina — Museo di Storia della Medicina, Padova, Italy

General informations

Padova Italy

2015

Education

Medicine

General description

Si tratta di un museo di nuova generazione che racconta, attraverso l'ausilio di tecnologie all'avanguardia e la possibilità di interazione da parte del visitatore, lo straordinario percorso della Medicina da disciplina antica a scienza moderna. Rispettando il contesto padovano in cui è inserito, il museo pone l'accento sulla storia e sul ruolo rivestito dalla Scuola medica patavina.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	-

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Developer, Museum curator, Artist, Communication, Engineer, Researcher, Architect, Psychologist, Doctor, Humanistic subject expert*

Case study experience

Tech used	*VR, AR, projection, Audio system*
Technological set up	*HMD, tablets, multiscreen, projectors, audio system*
If temporary, experience duration	*permanent*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

12. Van Gogh Exhibition — Fever - Exhibition HUB

General informations

-

2018

Entertainment

Art, performance

General description

Exhibition around the world of the masterpieces of the artist Van Gogh: rooms with 360 projections and VR HMD. The immersive experience presents content of the artist animated in 3D animation with immersive sound effects.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	-

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Developer, Museum curator, Artist, Communication, Engineer, Scientific subject expert, Humanistic subject expert*

Case study experience

Tech used	*VR, 360 projection, Audio system, Light system*
Technological set up	*HMD, projectors, audio system*
If temporary, experience duration	*temporary*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

13. Palacio de la Aljafería

Play&Go Experience

General informations

Zaragoza, Aragón (Spain)

2015

Education

Cultural Heritage

General description

The Aljafería Palace is an architectural masterpiece of Mudejar art. The Aljafería is a millenary building that is fundamental for learning about the history of Aragon. This mobile application will guide you through its rooms giving details of what you can see:
- Visit / Itinerary to the palace.
- Recreations in Augmented Reality.
- Audio guide
- Images and videos of the monument

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*Video Gaming engine (Unity, Unreal, etc.)*

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	**Yes** | No

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Developer, Marketing, Communication*

Case study experience

Tech used	*AR*
Technological set up	*mobile*
If temporary, experience duration	*permanent*

Narration	**Yes** | No	Playful elements	**Yes** | No	Selection of users	Yes | **No**

14. Gymkana Camp de Morvedre

Play&Go Experience

General informations

Camp de Morvedre, Valencia (Spain)

2015

Education

Cultural Heritage

General description

The development of the Gymkana Camp de Morvedre, consisted of creating a tool that has generated a unique tourist experience based on a digital and gamified guide of the Camp de Morvedre county, and in which three elements are combined: web/app; QR codes and geolocation. It is a gymkhana that adds elements of mini-games (outdoor escape room) and search for clues in the territory (geocaching).

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*Genially platform*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Developer, Museum curator, Artist, Communication, Engineer, Researcher, Architect, Psychologist, Doctor, Humanistic subject expert*

Case study experience

Tech used	*AR*
Technological set up	*mobile*
If temporary, experience duration	*permanent*

Narration	**Yes** | No	Playful elements	**Yes** | No	Selection of users	Yes | **No**

15. Ruta Maestrat

Play&Go Experience

General informations

Maestrat, Castellón (Spain)

2021

Education

Cultural Heritage

General description

An application that uses geolocation to pinpoint routes and tours in the territory of Maestrat, which is located between the Mediterranean coast. You may choose between two hikers to accompany you in your adventure through the Maestrat, in which you will discover the soul of this territory through the cultural (Ànima Cultural), active tourism (Ànima Activa) and gastronomic (Ànima Gastro) resources.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*Video Gaming engine (Unity, Unreal, etc.)*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Developer, Marketing, Communication*

Case study experience

Tech used	*AR*
Technological set up	*mobile*
If temporary, experience duration	*permanent*

Narration	**Yes** | No	Playful elements	**Yes** | No	Selection of users	Yes | **No**

16. Ariadne's Fibres

La métonymie and Cervval

General informations

France, Paris, Forum des images

2018-present

Research

Art

General description

Cybernetic reflection for users, meteorological data and air quality, with infrared and color sensors, computers and monitors
This living mirror, a veritable place of exchange of images whiwh move through us, is able to reveal 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. The Ariadne's Fibres transmit information, convey images and drops of images: these we hold, those that hold us, which make us, those we share.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*Coding software, Cervval custom game engine*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	**Yes** | No

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Developer, Artist*

Case study experience

Tech used	*Audio system, Body-tracking systems, Video wall*
Technological set up	*Computer, Multiscreens, Directional/ parametric loudspeakers*
If temporary, experience duration	*permanent*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

17. Digital dynamic version of Chinese ancient painting "Along the River During the Qingming Festival"

Crystal CG

General informations

Shanghai Art Museum, Shanghai, China

2010

Education

Cultural Heritage

General description

Qingming Festival" is a dynamic version of the famous work by the Northern Song Dynasty painter Zhang Zeduan in China (1085-1145). The work was first exhibited at the China Pavilion at the 2010 World Expo in Shanghai, and currently exhibited permanently in Shanghai Art Museum.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	-

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Developer, Museum curator*

Case study experience

Tech used	*VR, 360 Projection, Audio system, Light system*
Technological set up	*Computer, Projectors, Multiscreens, Directional/ parametric loudspeakers, Light systems*
If temporary, experience duration	*permanent*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

18. Illuminated Art Attisholz

Projektil, MAAG Music & Arts AG, halter, Attisholz-Areal

General informations

Switzerland, Solothurn, Attisholz Areal

2020

Education

Cultural Heritage

General description

The Zurich artist collective Projektil creates a choreographed show at Illuminated Art Attisholz, presenting the most important works of two creators who have had a decisive influence on Swiss painting. At 8,000 square meters, this is the largest immersive museum Switzerland has ever seen. At the Attisholz-Areal, visitors could expect a 360-degree journey through some of the most famous works of the two renowned artists. Illuminated Art uses state-of-the-art video projectors to create an immersive art gallery in which the viewer experiences the paintings of the legendary Swiss painters in a completely new way.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	-

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Museum curator, Artist*

Case study experience

Tech used	*Projection, Audio system*
Technological set up	*Projectors*
If temporary, experience duration	*temporary, 3 months*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

19. Chaplin's World

Grévin

General informations

Switzerland, Corsier-sur-Vevey

2023

Education

Cultural Heritage

General description

This "case study" describes a recent museum with many immersive elements. The process of creation of the museum is neither known in detail nor analysed. The descriptions in the present form are based only on a visit of the museum and the consideration of the website of the museum.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	-

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Museum curator*

Case study experience

Tech used	*AR, Projection, Audio system, Light system*
Technological set up	*Computer, Projectors, Multiscreens, Directional/ parametric loudspeakers, Light installations*
If temporary, experience duration	*permanent*

Narration	Yes | **No**	Playful elements	**Yes** | No	Selection of users	Yes | **No**

20. The Eye of Mars

La métonymie, Donner des Ailes, Cervval, Institut d'Astrophysique Spatial, Cloître des Billettes

General informations

Billettes Cloister, Paris, France

2017

Research

Art

General description

The Eye Mars mixes science, technology, imagination and dreaming to focus on the special relationship between humans and Mars. The Eye of Mars develops this particular relationship to curiosity, and therefore to exploration and learning. This artwork makes curiosity and implies us in a research exercise on curiosity. It makes us explore and experiment the discovery process itself. It widely opens an uncommon window on a topic of scientific interest and on a place of common imagination: Mars.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*Coding software, Python with glumpy; javascript and openGL; MaxMSP*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	**Yes** | No

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Developer, Artist*

Case study experience

Tech used	*360 Video, Projection, Audio system, Body-tracking systems, Spheric videoprojection*
Technological set up	*Computer, Projectors, Directional/parametric loudspeakers, Interactive sphere*
If temporary, experience duration	*1 night*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

21. The Hidden Music of Leonardo

Doulce Mémoire, La métonymie, Cervval, Louvre Museum

General informations

France, Paris, Louvre

2019

Entertainment

Art

General description

Real-time setting of a virtual scene for the creation of multi-viw point dynamic projection masks with sixteen depth sensors, eighteen computers and three video projectors. Doulce Mémoire concert with four musicians and two singers.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*c#, openGL, webGL, javascript*

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Developer, Artist, Engineer, Researcher, Musicologist and curator*

Case study experience

Tech used	*AR, Projection, Light system*
Technological set up	*Computer, Projectors, Light installations, Interactive walls/floor, 3D real time virtual stage*
If temporary, experience duration	*70 min*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

22. See me through you

La métonymie, IR4M, Lab-STICC, LIMSI, IAS, Département Arts-Musique of the Université d'Evry Val d'Essonne, CNRS, Université Paris-Sud

General informations

FRA Paris, Cité des sciences et de l'industrie

2015-2023

Research

Art

General description

See me through you tries to make visible the distortions of spacetime and tangible the relativity between the visitor and the others through an interactive 360° video projection where the visitor is both the observer and the distant celestial body of the others at the same time. Visitors see themselves through them.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*Java, OpenGL for prototyping then c#, OpenGL, WebGL*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	**Yes** | No

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Developer, Artist*

Case study experience

Tech used	*360 Video, Projection, Audio system, Body-tracking systems*
Technological set up	*Computer, Projectors, Interactive walls/floor*
If temporary, experience duration	*9 months*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

23. Primary Intimacy of being

La métonymie, IR4M, LIMSI, IEF, LRI, SHFJ, Département Arts-Musique of the Université d'Evry Val d'Essonne, CNRS, Université Paris-Sud.

General informations

France, Paris, Museum of art and craft

2011-

Research

Art

General description

Mirrors augmented with X rays, nuclear imaging, and magnetic resonance imaging with sensors, gender recognition, computers and 75" screens. Triptych in lacquered glass and oak wood. A mirror reflects a human being, a woman, a man, as revealed by X rays imaging, positron emission tomography or magnetic resonance imaging. It's a volume image, giving access to the third dimension of space for three singular avatars of the spectator.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | **Field** | Lab

Software used: *c#, openGL, webGL, javascript*

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: **Yes** | No

Personalization of the experience: **Yes** | No

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: **Yes** | No

Roles involved: *Developer, Artist, Engineer, Researcher, Psychologist, Doctor, Scientific subject expert, Humanistic subject expert*

Case study experience

Tech used: *AR, Projection, Body-tracking systems, MRI,*

Technological set up: *Computer, Multiscreens, Interactive walls/floor*

If temporary, experience duration: *Permanent*

Narration: Yes | **No** | Playful elements: Yes | **No** | Selection of users: Yes | **No**

24. NAO

IncluTIC (University of Alicante)

General informations

Alicante, Valencian Community (Spain)

2023

Education

Educational

General description

The Inclusive Education and Technology (IncluTIC) research group at the University of Alicante (UA) is developing a pioneering project in the combined application of immersive virtual reality and social robotics to improve communication for people with Autism Spectrum Disorder (ASD), with the help of the NAO robot, which plays the role of personal assistant.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | **Field** | Lab

Software used: *Video Gaming engine (Unity, Unreal, etc.)*

Interaction Modalities

The users: Could move | **are stationary**

Interaction w physical/digital objects: **Yes** | No

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: **Yes** | No

Roles involved: *Psychologist, Teacher*

Case study experience

Tech used: *VR, Social robotics*

Technological set up: *Headset / visor, Computer*

If temporary, experience duration: *Pilot case*

Narration: Yes | **No** | Playful elements: Yes | **No** | Selection of users: **Yes** | No

25. Do Not Open

Quasar Dynamics

General informations

Valencia (Spain)

2022

Entertainment

Gaming

General description

Do not Open is the first Virtual Reality videogame created in Valencia. Thanks to an alliance of Nox Noctis, Quasar Dynamics and Lanzadera (Accelerator). DO NOT OPEN is a terrifying short and fast paced first-person escape-room experience, based on randomness in puzzle combinations, and classic survival-horror mechanics.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | Field | **Lab**
Software used	*Graphic, UX, 3D modeling, 3D render, Video Gaming engine, Coding software*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Developer, Marketing*

Case study experience

Tech used	*VR*
Technological set up	*HMD*
If temporary, experience duration	-

Narration	**Yes** | No	Playful elements	**Yes** | No	Selection of users	Yes | **No**

26. Exstasis

Odd Agency - Palermo

General informations

ITA, Sicily, Sta Caterina church, Palermo

2019

Entertainment

Cultural Heritage

General description

Exstasis is an immersive projection mapping project that illuminated the church of Santa Caterina d'Alessandria in Palermo: visitors are projected into a completely virtual environment, surrounding them with visual stimuli, music, and light effects, transporting them out of the surrounding space and breaking, for the whole performance.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*Graphic, 3D render software, Office suite*

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Developer, Artist, Marketing, Web developer / Sound designer / 3D artisti / VR specialist / Copywriter / Interaction designer / Interaction engineering /*

Case study experience

Tech used	*Projection, Audio system*
Technological set up	*Projectors, Directional/parametric loudspeakers*
If temporary, experience duration	*2 days*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

27. Skin awareness

Friendred

General informations

London, UK

2018

Research

Art

General description

Inspired by Merleau-Ponty's philosophical frameworks and body related theories, the first author produced an interactive performance, aiming to explore the dancers' body as embodied perception and the changes in the immersive space. 3 divergent settings were engineered in the performance to experiment with the capacity of bodily territory and space using immersive projection and light media.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | Field | **Lab**

Software used: *Graphic, UX, 3D modeling, 3D render, Video Gaming engine, Coding software OpenFrameworks, ofxSerial, ofxOsc, OfxIO, ofxPoco, ofxGUI and ofxDMX*

Interaction Modalities

The users: Could move | **are stationary**

Interaction w physical/digital objects: Yes | **No**

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: **Yes** | No

Roles involved: *Designer, Developer, Artist, Communication, Sound producer , Performer , Computation , Visual design & Interactive design , Cinematographer, Post Production*

Case study experience

Tech used: *Projection, Audio system, Light system*

Technological set up: *Projectors, loudspeakers, Laser*

If temporary, experience duration: *performance*

Narration: Yes | **No** Playful elements: Yes | **No** Selection of users: Yes | **No**

28. Trembling horizons

Olafur Eliasson

General informations

Turin, Rivoli, Castello di Rivoli

2022/23

Research

Art

General description

Olafur Eliasson transforms the Castello di Rivoli by installing a new series of six immersive wedge-shaped optical device-like artworks in the long gallery. Inside each, the viewer can watch complex patterns unfold in fluid motion within a 360-degree panoramic space that seems more expansive than physically possible – through mirrors and light projections.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | Field | **Lab**

Software used: -

Interaction Modalities

The users: Could move | **are stationary**

Interaction w physical/digital objects: Yes | **No**

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: Yes | **No**

Technicians involved: **Yes** | No

Roles involved: *Artist*

Case study experience

Tech used: *Light systems*

Technological set up: *Light installations, Water surfaces, mirrors*

If temporary, experience duration: *temporary*

Narration: Yes | **No** Playful elements: Yes | **No** Selection of users: Yes | **No**

29. Infinity Room — Refik Anadol

General informations

Istanbul, Biennal- Zorlu performing art

2015

Research

Art

General description

'Infinity Room' is an immersive environment project by Refik Anadol: it consists of a room with mirrored walls in which it is projected a sound responsive abstract image, surrounding thanks to reflection the visitors

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	-

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Media Artist, Sound designer*

Case study experience

Tech used	*Projection, Audio system*
Technological set up	*Projectors, Directional/parametric loudspeakers, Mirror*
If temporary, experience duration	*temporary*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

30. Falls from the Sky, Aerosplane, Flutter — Michael Brewster

General informations

Villa Panza, Varese, Italy

1993

Research

Art

General description

Michael Brewster's acoustic sculpture: Falls From The Sky, Aereosplane and Flutter. In a completely bare room, a single speaker emits a series of electronic tones that, reverberating off the walls of the room, create a sound space made up of zones of different volume and tonal content.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | Field | **Lab**
Software used	-

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	Yes | **No**
Technicians involved	Yes | **No**
Roles involved	*Sound Artist*

Case study experience

Tech used	*Audio systems*
Technological set up	*Audio systems*
If temporary, experience duration	*permanent*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

31. Immersive Space Series

31. OOT

General informations

San Francisco Bay, Youtbe and Google Offices

2016-2020

Health

Education

General description

Immersive Spaces series is a project in progress that explores different working contexts and different types of rooms, created as circumscribed spaces, aimed at providing an intense immersive experience.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	-

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Researcher, Architect*

Case study experience

Tech used	*Audio system, Light system*
Technological set up	*Loudspeakers, Light installations*
If temporary, experience duration	*permanent*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	**Yes** | No

32. I AM (VR)

Susanne Kennedy - Markus Selg

General informations

Triennale di Milano

2022

Research

Art

General description

In I AM (VR), Susanne Kennedy and multimedia artist Markus Selg (in collaboration with Rodrik Biersteker) experiment with the possibilities of immersive theatre, exploring new, richer dimensions. The experience is a psychedelic trip, a total theatrical experience that seems to know no outside.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | Field | **Lab**
Software used	*video engine, 3D modeling, 3D rendering*

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	Yes | **No**
Technicians involved	Yes | **No**
Roles involved	*Designer, Developer, Sound Design / Copywriter / Dramaturgy*

Case study experience

Tech used	*VR*
Technological set up	*Headset / visor*
If temporary, experience duration	*March 16 – 20 2022*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

33. Anima Mundi

Odd Agency

General informations

Italy, Palermo, Orto Botanico, Via Lincoln 2

2021

Entertainment

Cultural Heritage

General description

A magic experience comes to life into an imaginary world populated by the light creatures hidden among the gnarled trunks and the majestic foliage of the Botanical Garden. Throughout the walk, the visitor has to follow Jinn, the genius loci of the Garden, on a journey with his friends Puch, Yara, Sun and Kurma to save their ecosystem and the entire world from the dangers of global warming.

Link to case study
webpage / videos / photos
/ additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*Graphic software (Adobe Illustrator, Figma, etc.), 3D render software (Blender, Keyshot, Cinema 4D, etc.), Office Suite*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Developer, Artist, Communication*

Case study experience

Tech used	*Projection, Audio system*
Technological set up	*Projection, Audio system*
If temporary, experience duration	*temporary*

Narration	**Yes** | No	Playful elements	**Yes** | No	Selection of users	Yes | **No**

34. Earth

Odd Agency

General informations

Church of San Francesco d'Assisi, Palermo, ITA

2020

Entertainment

Cultural Heritage

General description

Projection of 3D animation on the church of San Francesco D'assisi inside wall.
The theme of the performance is the relationship between man and nature, the interdependence between the planet and the beings that populate it. A theme, that of the relationship between human beings and other living creatures, dear to St. Francis and made explicit in his Cantico Delle Creature.

Link to case study
webpage / videos / photos
/ additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*Graphic software (Adobe Illustrator, Figma, etc.), 3D render software (Blender, Keyshot, Cinema 4D, etc.), Office Suite*

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Developer, Artist, Marketing, Communication*

Case study experience

Tech used	*VR*
Technological set up	*Headset / visor*
If temporary, experience duration	*temporary*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

35. Lightroom - Bigger & Closer

David Hockney

General informations

Lightroom space, London, UK

2021

Entertainment

Art

General description

Using large-scale projection in a remarkable new space, David Hockney takes us on a personal journey through sixty years of his art. Lightroom's vast walls and revolutionary sound system enable us to experience the world through Hockney's eyes. His life-long fascination with the possibilities of new media is given vibrant expression.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | Field | **Lab**

Software used: *Graphic software (Adobe Illustrator, Figma, etc.), 3D render software (Blender, Keyshot, Cinema 4D, etc.), Office Suite*

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: Yes | **No**

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: **Yes** | No

Roles involved: *Designer, Developer, Artist, Editor, Sound Designer, Animators, Video programmer*

Case study experience

Tech used: *Projection, Audio system, LED walls*

Technological set up: *Projectors, Multiscreens, loudspeakers, light*

If temporary, experience duration: *temporary*

Narration: **Yes** | No | Playful elements: Yes | **No** | Selection of users: Yes | **No**

36. Goliath

ANAGRAM

General informations

online

2021

Entertainment

Awareness

General description

GOLIATH: PLAYING WITH REALITY is a 25-minute animated virtual reality experience about schizophrenia, gaming and connection. Winner of the Grand Jury Prize for Best VR Immersive Work at the 78th Venice International Film Festival (2021) Nominated for a News & Documentary Emmy Award in the Outstanding Interactive Media Innovation category (2022)

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | **Field** | Lab

Software used: *Graphic software , 3D modeling software, 3D animation software, 3D render software, Video Gaming engine*

Interaction Modalities

The users: Could move | **are stationary**

Interaction w physical/digital objects: Yes | **No**

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: Yes | **No**

Roles involved: *Designer, Developer, Artist, Producers, Animators, Sound design, Modelers, Director and Writer*

Case study experience

Tech used: *VR*

Technological set up: *Headset / visor*

If temporary, experience duration: *permanent*

Narration: **Yes** | No | Playful elements: Yes | **No** | Selection of users: Yes | **No**

37. Rome's Invisible City VR

BBC - ScanLAB

General informations

online

2017

Education

Cultural Heritage

General description

This prototype allows you to explore Rome's magnificent Pantheon and the underground quarry the Romans mined to build it in stunning 3D virtual reality. The clever bit is that you won't need any fancy kit to use it as it works through a web browser on your phone or tablet, but if you have a Cardboard viewer then even better!

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | Field | **Lab**
Software used	*Graphic software (Adobe Illustrator, Figma, etc.), 3D render software (Blender, Keyshot, Cinema 4D, etc.), Office Suite*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Museum curator, Humanistic subject expert, 3D scanning studio*

Case study experience

Tech used	*VR*
Technological set up	*Headset - visor*
If temporary, experience duration	*temporary*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

38. The Dreamachine

Collective Act

General informations

London, UK

2022

Research

Art

General description

IN THE late 1950s, when altered states of consciousness were all the rage, the artist Brion Gysin invented a drug-free route to psychedelic euphoria. His Dreamachine – a spinning cylinder that shines flashing lights onto a viewer's closed eyes – was intended as a shortcut to spiritual enlightenment for the masses.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*see interviews results*

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	**Yes** | No

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	Yes | **No**
Roles involved	*see interviews results*

Case study experience

Tech used	*light and audio systems*
Technological set up	*light and audio systems*
If temporary, experience duration	*temporary*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

39. Oculus Nohlab

NohLab

General informations

Istanbul, Tophane-i Amire

2016

Entertainment

Art

General description

Oculus was a site-specific installation designed for Istanbul Design Biennale in 2016, and exhibited in Tophane-i Amire. A selection of HAS Architects' projects is presented in a performance that blends digital technology with spatial design, forming a synthesis between the past and the present within the magical atmosphere of the historical Single-Dome Hall of the Imperial Arsenal.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | Field | **Lab**
Software used	-

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Technical Producer, Sound Design, Graphic Design*

Case study experience

Tech used	*Projection, Audio system, Light system*
Technological set up	*Projectiors, Audio system, Light system*
If temporary, experience duration	*temporary*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

40. MMANZONI 23 – Perpetual Immersive Experience

via Manzoni 23

General informations

Milan, via Manzoni 23

2021

Research

Art

General description

Manzoni 23 is a digital urban experience permanently available in the heart of the fashion district. It is a video-show projection on the walls of a courtyard in Milan.
An artistic intervention created by Immersive Media Studio with the aim of enriching the already beautiful internal courtyard - just renovated - located at number 23 of the same via Manzoni. It is located 100 meters from the Teatro alla Scala and 50 meters from the Montenapoleone metro station.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	-

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	Yes | **No**
Roles involved	*Designer, Developer*

Case study experience

Tech used	*Projection*
Technological set up	*Projectors*
If temporary, experience duration	*permanent*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

41. Giostra del Saracino

CarraroLAB

General informations

Arezzo, Tuscany, Italy

2019

Entertainment

Cultural Heritage

General description

The exhibition itinerary "The colors of the Giostra", inaugurated in Arezzo, allows an immersive experience of the Giostra del Saracino. VR allows the visitor to "immerse" himself in the Saracino, during the historical procession, in jousting ceremonies, in neighborhood life, in the performances of musicians and flag-wavers, in the entrance to Piazza Grande and in the carousel itself

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | Field | **Lab**
Software used	*Graphic software (Adobe Illustrator, Figma, etc.), 3D render software (Blender, Keyshot, Cinema 4D, etc.), Office Suite*

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, developer*

Case study experience

Tech used	*(VR), 360 Video, Audio system*
Technological set up	*Headsets, Projectors, loudspeakers*
If temporary, experience duration	*permanent*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

42. Deep Space 8K

Ars Electronica

General informations

Ars Electronica, Linz, Austria

2022

Research

Art

General description

The Deep Space 8K is not only a room in which breathtaking pictures and videos in 3-D can be shown with unmatched precision, but also a place at which it is possible to refashion the exhibited material.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*see interviews results*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	Yes | **No**
Roles involved	*see interviews results*

Case study experience

Tech used	*projection, audio systems*
Technological set up	*projection, audio systems*
If temporary, experience duration	*permanent*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

43. Mona Lisa VR

Louvre Museum

General informations

Louvre, Paris, France

2019

Entertainment

Cultural Heritage

General description

Thanks to the latest scientific research, the experience highlights the various techniques used by Da Vinci in his creation process and gives lots of information about the model's identity. Participants will be able to discover the secrets of an artwork that remains the most fascinating masterpiece ever created.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | Field | **Lab**

Software used: *3D modeling, 3D animation, 3D render software, Video Gaming engine*

Interaction Modalities

The users: Could move | **are stationary**

Interaction w physical/digital objects: **Yes** | No

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: Yes | **No**

Roles involved: *Designer, Developer, Museum curator*

Case study experience

Tech used: *VR*

Technological set up: *Headsets, visors*

If temporary, experience duration: *permanent*

Narration: **Yes** | No | Playful elements: Yes | **No** | Selection of users: Yes | **No**

44. Dreams of Dalì

Dalì Museum

General informations

St Petersburg, FL, USA, Dali Museum

2016

Entertainment

Cultural Heritage

General description

Dreams of Dalí is a fully immersive 3-D environment available free to visitors to the Disney & Dali exhibit. Everyone may explore a 360-video of Dreams of Dalí from a desktop computer or mobile device"

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | **Field** | Lab

Software used: *3D modeling software , 3D animation, 3D render, Video Gaming engine*

Interaction Modalities

The users: Could move | **are stationary**

Interaction w physical/digital objects: Yes | **No**

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: Yes | **No**

Roles involved: *Designer, Developer, Museum curator*

Case study experience

Tech used: *projection, audio systems*

Technological set up: *projection, audio systems*

If temporary, experience duration: *permanent*

Narration: **Yes** | No | Playful elements: Yes | **No** | Selection of users: Yes | **No**

45. MoMa virtual tour

MoMa

General informations

MoMa, New York, USA

-

Education

Cultural Heritage

General description

It is a virtual tour by a 360 video content on some of the most iconic artwork inside MoMa

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | **Field** | Lab

Software used: -

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: **Yes** | No

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: Yes | **No**

Roles involved: *Developer, Museum curator*

Case study experience

Tech used: *360 Video*

Technological set up: *Computer, Smartphone, Tablet*

If temporary, experience duration: *permanent*

Narration: Yes | **No** Playful elements: Yes | **No** Selection of users: Yes | **No**

46. Kremer Museum

Dalì Museum

General informations

online

2017

Education

Cultural Heritage

General description

Kremer Foundation decided to realize a completely virtual museum inserting all the real artwork they have from dutch painters. You can download the app and play it on VR headsets and devices

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | **Field** | Lab

Software used: *3D modeling software , 3D animation, 3D render, Video Gaming engine*

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: Yes | **No**

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: Yes | **No**

Roles involved: *Designer, Developer, Museum curator, Architect*

Case study experience

Tech used: *VR*

Technological set up: *headset/visor*

If temporary, experience duration: *permanent*

Narration: Yes | **No** Playful elements: Yes | **No** Selection of users: Yes | **No**

47. The Anatomy Lesson of Dr. Nicolaes Tulp — MoMa

General informations

Maurithsius museum, The Hague, NL

2019

Education

Cultural Heritage

General description

The award-winning Rembrandt Reality app lets you travel back in time to the year 1632. After entering Amsterdam's anatomical theatre, you get to look over Rembrandt's shoulder and see how Dr. Tulp and his fellow physicians examine the body of the executed criminal Aris Kindt. It is an AR application to explore the painting details from everywhere.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | Field | **Lab**
Software used	*3D modeling software (SolidWorks, Rhino, Maya, etc.), 3D render software (Blender, Keyshot, Cinema 4D, etc.), 3D scanning softwares*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	Yes | **No**
Roles involved	*Designer, Developer, Museum curator*

Case study experience

Tech used	*AR*
Technological set up	*Mobile, Smartphone, Tablet*
If temporary, experience duration	*permanent*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

48. Infinity Mirror Rooms — Yayoi Kusama

General informations

Hirshhorn Museum, Washington, DC

2017

Entertainment

Art

General description

Over the course of her career, the artist has produced more than twenty distinct Infinity Mirror Rooms, and the Hirshhorn's exhibition—the first to focus on this pioneering body of work—is presenting six of them.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	-

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	**Yes** | No
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	Yes | **No**
Roles involved	*Designer, Developer, Museum curator, Artist*

Case study experience

Tech used	*Mirroring effect of objects*
Technological set up	*Mirrors*
If temporary, experience duration	*temporary*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

49. Rain Room

Random International studio

General informations

-

2012

Research

Art

General description

Human presence prevents the rain from falling, creating a unique atmosphere and exploring how human relationships to each other and to nature are increasingly mediated through technology. Upon entering the installation, visitors are simultaneously exposed to and protected from the water falling all around. Although the sound and smell of the rain are intense, its touch remains absen.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | **Field** | Lab

Software used: *custom software*

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: Yes | **No**

Personalization of the experience: **Yes** | No

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: Yes | **No**

Roles involved: *Designer, Developer, Artist, Engineer, Head Of Technology, Project Lead to the specific project, Coding*

Case study experience

Tech used: *water, injection moulded tiles, valves, pressure regulators, 3D tracking cameras, steel beams, grated floor*

Technological set up: -

If temporary, experience duration: *permanent*

Narration: Yes | **No** Playful elements: Yes | **No** Selection of users: Yes | **No**

50. Borderless

TeamLAB

General informations

Tokyo

2022

Entertainment

Art

General description

teamLab Borderless is a world of artworks without boundaries, a museum without a map created by art collective teamLab.
Artworks move out of rooms, communicate with other works, influence, and sometimes intermingle with each other with no boundaries.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | **Field** | Lab

Software used: *Graphic, 3D modeling, 3D animation , 3D render, Video Gaming engine, Coding software*

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: **Yes** | No

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: **Yes** | No

Roles involved: *Designer, Developer, Museum curator, Artist, Engineer, Architect, coding*

Case study experience

Tech used: *Projection, Audio system, Light system, Body-tracking systems*

Technological set up: *Projectors,speakers, Light, Interactive walls/floor*

If temporary, experience duration: *permanent*

Narration: Yes | **No** Playful elements: Yes | **No** Selection of users: Yes | **No**

51. CWRU Hololens

Case Western Reserve University

General informations

Cleveland, USA

2015

Educational

Medicine

General description

The case study reports the utilization of AR headsets such as Microsoft Hololens into Medicine and Healthcare university and research applications. The AR headset is here used in a demonstration by professors and students in order to analyze part of human brain and body.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | Field | **Lab**

Software used: *3D modeling, 3D render, game engine for the AR applications*

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: **Yes** | No

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: Yes | **No**

Roles involved: *Designer, Developer, Artist, Engineer, Medicine experts, Methodology for education experts*

Case study experience

Tech used: *AR*

Technological set up: *Headset-visor*

If temporary, experience duration: *permanent*

Narration: Yes | **No** | Playful elements: Yes | **No** | Selection of users: Yes | **No**

52. Mekorot FieldBit

FieldBit

General informations

Israel, Tel Aviv

2014

Training

Industry

General description

Israel's National Water Company uses AR smart glasses and mobile app platform to superimpose markings, messages, and diagrams directly onto the engineer's field of view.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | **Field** | Lab

Software used: *3D modeling, 3D render, game engine for the AR applications*

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: **Yes** | No

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: **Yes** | No

Roles involved: *Designer, Developer, Artist, Engineer*

Case study experience

Tech used: *AR headset*

Technological set up: *Epson Moverio glasses*

If temporary, experience duration: *permanent*

Narration: Yes | **No** | Playful elements: Yes | **No** | Selection of users: **Yes** | No

53. OSNI 2

Cartier

General informations

Paris, France

2022

Promotion

Industry

General description

OSNI 2 is a true immersive installation where light and fragrance simultaneously introduce the divine presence of the emblematic Panther creature. It shows the power of olfaction by matching all the senses and offers to the public the experience of synaesthesia. It really invites the visitors to renew their relationship with perfume through a direct and unique interaction. It's not light that enhances smell, but sight and smell that enhances each other.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | Field | **Lab**
Software used	-

Interaction Modalities

The users	Could move | **are stationary**
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	-

Case study experience

Tech used	*light and water*
Technological set up	*light system enlighting water falling*
If temporary, experience duration	*temporary*

Narration	**Yes** | No	Playful elements	Yes | **No**	Selection of users	Yes | **No**

54. Frameless

London / Dover

General informations

London, UK - Dover, USA

-

Entertainment

Cultural Heritage

General description

Frameless is a new space based in London where several rooms are dedicated to the projection of specific artwork by different artists in the last centuries. From Monet to Vang Gogh to other painters, their artworks are projected in order to let visitors feel immersed. Before the projection rooms, Frameless offers introudction panels explaining the artworks and the artists themselves.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested	Not | **Field** | Lab
Software used	*3D modeling, 3D animation, 3D render, game engine*

Interaction Modalities

The users	**Could move** | are stationary
Interaction w physical/digital objects	Yes | **No**
Personalization of the experience	Yes | **No**

Stakeholders

Multidisciplinary professionals involved	**Yes** | No
Technicians involved	**Yes** | No
Roles involved	*Designer, Developer, Artist, Exhibition curator*

Case study experience

Tech used	*projection*
Technological set up	*360 projectors*
If temporary, experience duration	*permanent*

Narration	Yes | **No**	Playful elements	Yes | **No**	Selection of users	Yes | **No**

55. Spaces in Between

Outernet

General informations

London, Outernet space

2022

Research

Art

General description

Studio Pixel Artworks with artist Rupert Newman has developed this art installation in the Outernet gallery in London, Tottenham. It consists of four display screens surrounding the visitors with digital art image responding to visitor movements. Background music is added to the experience.

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | Field | **Lab**

Software used: *Video animation, game engine, coding, 3D modeling, 3D rendering*

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: **Yes** | No

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: **Yes** | No

Roles involved: *Designer, developer, museum curator*

Case study experience

Tech used: *projection, multiscreen, body tracking*

Technological set up: *projectors, multiscreen, kinect*

If temporary, experience duration: *permanent*

Narration: Yes | **No** | Playful elements: Yes | **No** | Selection of users: Yes | **No**

56. Room to Breathe

Outernet

General informations

London, Outernet space

2022

Research

Healthcare

General description

Always Pixel Artworks studio has worked on a relaxing room inside Outernet London space: the visitors can enter anytime during the day and enjoy the realxing music, the walls projections with digital contents responding to the correct relaxing breathe rhitm we should take

Link to case study webpage / videos / photos / additional information

Case study process

Experience tested: Not | **Field** | Lab

Software used: *Video animation, game engine, coding, 3D modeling, 3D rendering*

Interaction Modalities

The users: **Could move** | are stationary

Interaction w physical/digital objects: **Yes** | No

Personalization of the experience: Yes | **No**

Stakeholders

Multidisciplinary professionals involved: **Yes** | No

Technicians involved: **Yes** | No

Roles involved: *Designer, developer, museum curator*

Case study experience

Tech used: *projection, multiscreen, body tracking*

Technological set up: *projectors, multiscreen, kinect*

If temporary, experience duration: *permanent*

Narration: Yes | **No** | Playful elements: Yes | **No** | Selection of users: Yes | **No**

Questionnaire

GENERAL INFO / BACKGROUND

Section dedicated to the general data collection of the compiler

1. Name and surname *

2. Company/University/Institution of reference *

   Mark only one oval.

   - ◯ POLIMI
   - ◯ EXODUS
   - ◯ MDL
   - ◯ TBG
   - ◯ UPSaclay
   - ◯ CERTH
   - ◯ CLINK
   - ◯ IFAAR
   - ◯ Other:

3. Contact email *

CASE STUDY

Section dedicated to the general data collection of the case study analized

4. Case study name *

5. Case study year *

6. Case study location (indicate the nation, city, specific location) *

7. Provide a general description of the case study (max 1.000 characters) *

8. Briefly indicate the reason behind the choice of this specific case study:

9. Specify the case study aim: *

Check all that apply.

- [ ] Awareness
- [ ] Promotion
- [ ] Education
- [ ] Research
- [ ] Dissemination
- [ ] Entertainment
- [ ] Training
- [ ] Maintenance
- [ ] Other:

10. Specify the field of application of the case study: *

Check all that apply.

- [ ] Industry
- [ ] Cultural heritage
- [ ] Architecture
- [ ] Art
- [ ] Design
- [ ] Education / school
- [ ] Medicine / healthcare
- [ ] Real estate
- [ ] Psychology
- [ ] Sport
- [ ] Automotive
- [ ] Marketing
- [ ] Entertainment
- [ ] Gaming
- [ ] Business / management
- [ ] Science / physics
- [ ] Astronomy
- [ ] Other: _____

CASE STUDY STAKEHOLDERS

Section dedicated to the case study stakeholders role and description

11. Which is the institution, company or other entity that commissioned the experience? *

Check all that apply.

- [ ] Cultural institutions
- [ ] Research center
- [ ] Company
- [ ] Studio / office
- [ ] Private investor
- [ ] Other: _____

12. Were multidisciplinary professionals involved in the design of the experience? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

13. Which are the roles of the stakeholders who took part in the design process of the experience? (Indicate the roles of all the actors involved) *

Check all that apply.

- [ ] Designer
- [ ] Developer
- [ ] Museum curator
- [ ] Artist
- [ ] Marketing
- [ ] Communication
- [ ] Engineer
- [ ] Researcher
- [ ] Architect
- [ ] Psychologist
- [ ] Doctor
- [ ] Teacher
- [ ] Scientific subject expert
- [ ] Humanistic subject expert
- [ ] Other: _____

14. Which stakeholders took part in the design of the experience? (Indicate the company names, if possible)

_____

15. Were technicians involved for the final set-up/installation of the experience? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

16. If yes, indicate which one

_____

_____

_____

_____

_____

17. What is the target user age of the experience? (If possible, indicate specific target categories) *

Check all that apply.

- [ ] Toddler
- [ ] Children
- [ ] Teenagers
- [ ] Young Adults
- [ ] Adults
- [ ] Elderly
- [ ] Other: _____

18. Is there a specific selection of the types of users involved? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

CASE STUDY EXPERIENCE

Section dedicated to the case study experience, interactions and users

19. Indicate the type of technology used during the experience *

Check all that apply.

- [ ] Virtual reality (VR)
- [ ] Augmented reality (AR)
- [ ] 360 Video
- [ ] Projection
- [ ] Audio system
- [ ] Light system
- [ ] Mobile application
- [ ] Vibro-tactile systems
- [ ] Body-tracking systems
- [ ] Other: _____

20. Indicate the type of device / technological set up used during the experience *

Check all that apply.

- [ ] Headset / visor
- [ ] Computer
- [ ] Smartphone
- [ ] Projectors
- [ ] Multiscreens
- [ ] Directional/parametric loudspeakers
- [ ] Tablet
- [ ] Touch screens
- [ ] Interactive tables
- [ ] Interactive kiosks
- [ ] Controller/joystick
- [ ] Light installations
- [ ] Laser
- [ ] LED systems
- [ ] Video recording
- [ ] Audio recording
- [ ] Haptic gloves
- [ ] Interactive walls/floor
- [ ] Other: _____

21. If the experience consists of an exhibition/installation, is it temporary or permanent?

Mark only one oval.

- ◯ Temporary
- ◯ Permanent
- ◯ Other: _____

22. If temporary, indicate the duration of the experience

_____

23. Which senses are involved during the experience? *

Check all that apply.

- [ ] Sight
- [ ] Touch
- [ ] Taste
- [ ] Hearing
- [ ] Smell
- [ ] Other: _____

24. During the experience, does the user move in space freely, or is he stationary? *

Mark only one oval.

- ◯ He/she moves
- ◯ Stationary
- ◯ Other: _____

25. Can the user interact with physical or digital objects during the experience? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

26. If yes, what are the main interaction modalities?

_____

_____

_____

_____

_____

27. Is the experience personalized to the individual user? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

28. How is it personalized?

_____

_____

_____

_____

_____

29. During the experience, is there a narration (e.g. initial and final storytelling) of the contents? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

30. During the experience, are presented playful elements (e.g. levels, badge acquisition, etc.)? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

31. Is the experience collaborative/multi-user? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

32. Can the user interact with other people during the experience? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

33. If yes, what are the main interaction modalities?

_____

_____

_____

_____

_____

CASE STUDY EXPERIENCE DESIGN PROCESS

Section dedicated to the case study experience design process

34. Indicate in which context the experience has been tested: *

Mark only one oval.

- ◯ Field test
- ◯ Lab test
- ◯ Other: _____

35. If possible, indicate the design process adopted for the design of the experience or specify the steps followed:

_____

_____

_____

_____

_____

36. Which software has been used when designing the experience? *

Check all that apply.

- ☐ Graphic software (Adobe Illustrator, Figma, etc.)
- ☐ UX design software (Adobe XD, Figma, etc.)
- ☐ 3D modeling software (SolidWorks, Rhino, Maya, etc.)
- ☐ 3D animation software (Blender, Maya, etc.)
- ☐ 3D render software (Blender, Keyshot, Cinema 4D, etc.)
- ☐ Video Gaming engine (Unity, Unreal, etc.)
- ☐ Data visualization
- ☐ AI Software
- ☐ Coding software
- ☐ I don't know
- ☐ Other: _____

37. Is the software adopted as open source? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ I don't know
- ◯ Other: _____

EXTERNAL DOCUMENTS

Upload any document related to the case study (check cc availability or copyright)

38. Insert **links** to documents / scientific articles / videos / photos / descriptions / websites that may be interesting to better understand the case study: *

39. Insert a couple of reference **images**. Please use nameofcase_1, nameofcase_n

    Files submitted:

40. Insert a **video** of the experience, if possible.

41. Indicate the contact of a reference figure for further information on the case study (Name, Surname and mail address)

Thank you so much for compiling the case study form!