Éternelle Notre-Dame: From Multidisciplinary Design to Longitudinal Evaluation of the Large-Scale Cultural Heritage Virtual Reality Experience

Loris Belin [INSEAC | *loris.belin.auditeur@lecnam.net*]
Jean-Baptiste Scharffhausen [UFPE | *jean-baptiste.scharffhausen@ufpe.br*]
Leonardo Souza Silva [UFMS | *leonardo.ufms@gmail.com*]
Fatima L. S. Nunes [EACH - USP | *fatima.nunes@usp.br*]
João Marcelo Teixeira ✉ [EACH - USP / UFPE | *joao.teixe@ufpe.br*]

✉ *Universidade Federal de Pernambuco, Av. Prof. Moraes Rego, 1235, Cidade Universitária, Recife - PE, CEP:50670-901, Brazil.*

Abstract: *Background:* When a blaze devoured the spire of Notre-Dame in April 2019, the cathedral's future suddenly hinged on memory, measurement, and imagination. *Purpose:* Eternelle Notre-Dame responds by fusing sub-millimeter laser scans, archival iconography, and dramaturgical storytelling into a free-roam virtual-reality expedition that accommodates one hundred untethered visitors inside a 500 m² arena. *Methods:* This paper retraces the multidisciplinary pipeline behind that feat—from the historiographic choices that shaped a nine-scene narrative, through the ultra-low-latency networking stack that synchronizes Meta Quest headsets at 90 Hz, to the safety, accessibility, and comfort heuristics distilled from a three-week pilot deployment. We then triangulate ethnographic observations with 98 unsolicited online reviews collected over 42 months. *Results:* The analysis reveals how corporeal behavior, memorial imagination, and technological mediation intertwine to produce awe, vertigo, or scepticism in different audience segments. *Conclusion:* The findings not only validate crowd-scale heritage VR as a viable mode of public history but also surface open design tensions—between historicity and spectacle, agency and safety, immersion and reflection—that future cultural XR experiences must negotiate.

Keywords: Virtual Reality, Cultural Heritage, Location-based VR, Notre-Dame, User Experience Evaluation

1 Introduction

On April 15, 2019, millions around the globe watched as flames consumed the roof and spire of Notre-Dame de Paris (Figure 1). Beyond the immediate physical devastation, the fire threatened a UNESCO World Heritage site that had stood for over eight centuries and attracted more than 13 million visitors annually [UNESCO, 2019]. The disaster triggered an unprecedented wave of international solidarity and fundraising, but it also catalysed a broader discussion inside the digital-heritage community about how emerging immersive media could help protect— and share—the cathedral's tangible and intangible values.

Figure 1. Fire in the roof of Notre Dame. Credits: GodefroyParis

In parallel with ongoing restoration work, *Éternelle Notre-Dame* was conceived as a large-scale location-based VR experience (LBE) that would enable the public to explore meticulously reconstructed epochs of the monument while directly supporting the reconstruction fund [Orange Group and Amaclio Productions, 2022]. The project builds on two decades of virtual-heritage research demonstrating the educational and preservation potential of real-time 3D environments [Addison and Gaiani, 2000; Bekele *et al.*, 2018], yet it pushes the envelope by staging the experience inside a 500m² free-roam arena capable of hosting up to one hundred simultaneous visitors (Figure 2).

Creating a historically faithful, technically robust and emotionally engaging experience at this scale required an interdisciplinary pipeline spanning high-resolution laser scanning, photogrammetry, art-historical scholarship, real-time graphics optimisation and human–computer-interaction design (Figure 3).

Similar endeavours—such as the interactive tour of the Church of Santa Maria della Purita [Piscitelli, 2023] and Rome Reborn2.0 [Dylla *et al.*, 2010]—typically focus on desktop or small room-scale deployments; *Éternelle Notre-Dame* adds challenges of crowd flow, low-latency networking and multilingual narrative delivery.

Evaluating experiential quality in LBE settings is notoriously complex because traditional laboratory instruments can disrupt the naturalistic context that attracts visitors in the first place [Falk and Dierking, 2016]. In response, we
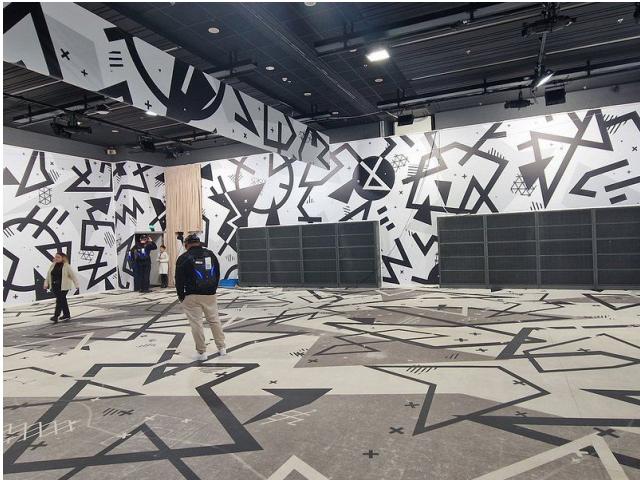
Figure 2. Picture found in one of the visitors' review on TripAdvisor.
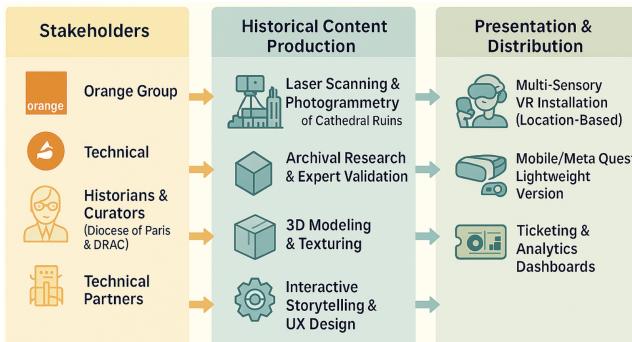

Figure 3. Éternelle Notre-Dame production pipeline.

adopt an unobtrusive strategy: mining and analysing 98 unsolicited TripAdvisor reviews published between January 2022 and May 2025. This approach complements in-house maintenance logs and affords a longitudinal perspective on perceived authenticity, comfort and operational efficiency.

The remainder of this paper is organized as follows. Section 2 positions our contribution within the growing body of immersive-heritage scholarship. Section 3 retraces the multidisciplinary workflow that guided the historical reconstruction of Notre-Dame, from laser scans to narrative framing. Section 4 details the system architecture—hardware, networking, and safety layers—that sustains crowd-scale free-roam VR. Section 5 turns to the visitor's perspective, explaining the interaction model and comfort safeguards embedded in the experience. Section 6 reports on a three-week pilot deployment conducted at the Cité des Télécoms, while Section 7 extends the evaluation by mining 98 unsolicited TripAdvisor reviews collected over three and a half years. Section 8 synthesizes technical and evaluative findings into design recommendations for large-scale cultural VR, and Section 9 concludes with key insights and avenues for future work.

2 Related Work

Research in virtual heritage has progressed from single-screen visualizations to fully immersive, location-based experiences that couple free-roam interaction with curated narratives. Foundational work established real-time 3D graphics as a means for preservation and public engagement [Addison and Gaiani, 2000], while subsequent surveys synthesized the tech-

nical and curatorial tensions—most notably the balance between historical accuracy, visual appeal, and user experience across AR/VR/MR systems [Bekele *et al.*, 2018]. Large-scale urban reconstructions such as *Rome Reborn 2.0* demonstrated both the ambition and the engineering demands of city-scale modeling for interpretation and education [Dylla *et al.*, 2010], and, in parallel, the VR community has explored how to prototype and evaluate multi-user, location-based experiences before deployment [Hilton *et al.*, 2023].

Within museums, a growing body of work has moved beyond passive viewing toward embodied learning. Deployments like *DinosaurVR* report how room-scale interaction and spatial storytelling can enrich a science exhibition [Souza *et al.*, 2023], while *XiloVR* uses a hands-on simulation to preserve the practice of woodcutting as intangible heritage [Costa *et al.*, 2024]. Broader curatorial initiatives have examined how VR can "virtual-realitize" museum offerings—reframing galleries, circulation, and interpretation around immersive media [Shih, 2023]. In cultural-specific settings, extended-reality exhibits such as the Sanxingdui bronzes have been used to study interaction design and learning outcomes in interactive virtual museums [Huang *et al.*, 2025]. Complementarily, digital-heritage research has investigated how gamification shapes tourist engagement with built heritage [Garcia *et al.*, 2024] and how metaverse infrastructures (e.g., NFTs) might support new preservation and sustainability models [Silva *et al.*, 2024].

These experiences depend on rigorous content pipelines, increasingly aided by recent vision foundation models. For heritage assets with complex geometry and ornamentation, semantic segmentation has been applied to Notre-Dame de Paris datasets to support documentation and analysis [Réby *et al.*, 2023]. Related studies employ the Segment Anything Model (SAM) to bridge scan-to-structural analysis workflows in cultural-heritage engineering [Galanakis *et al.*, 2024], and to obtain consistent part segmentation from crowdsourced imagery via SfM-guided labeling [Sharma and Jana, 2025]. Together, these efforts show how digitization (laser scanning, photogrammetry) and AI-assisted interpretation can accelerate reconstruction while preserving scholarly traceability.

Finally, visitor studies provide the interpretive frame for judging impact. The museum experience model emphasizes that personal, social, and physical contexts jointly shape meaning-making [Falk and Dierking, 2016]. Recent immersive-museum reports echo this view, showing that presence, interaction design, and narrative coherence are critical to engagement and learning in VR-based exhibits [Huang *et al.*, 2025; Souza *et al.*, 2023].

Prior work collectively demonstrates the promise and complexity of immersive cultural-heritage systems: the need to align curatorial aims with scalable content pipelines, to plan for multi-user, location-based operation, and to evaluate experiences through robust visitor-centered frameworks. Our contribution builds on these lessons by combining free-roam, crowd-scale VR with multi-epoch reconstruction and by adopting evaluation strategies that integrate operational data with organic visitor narratives—while maintaining methodological transparency from capture to interpretation.

3   Creation of the Historical Content

In the absence of extensive archival documentation, our examination of the historical and heritage strategy underpinning Eternelle Notre-Dame rests on three interrelated evidential strata: the constellation of stakeholders who orchestrated the project, the corpus of their public statements, and the semiotic fabric of the experience itself. The objective is not to retrace the entire creative workflow but to distil the main curatorial impulses that ultimately shaped the virtual reconstruction.

The initiative originated with Orange, the French telecommunications group, which announced its intention to support a virtual re-imagining of the cathedral shortly after the April 2019 fire. Orange subsequently assembled a consortium whose composition already signals a dominantly heritage-driven agenda. Amaclio Productions contributes its expertise in staging large-scale spectacles at emblematic French monuments, positioning the project within a framework of "heritage enhancement." Emissive, recognised for pioneering immersive virtual-reality installations, provides the technical backbone, while stage director Bruno Seillier—renowned for historically themed productions at Puy du Fou—oversees artistic coherence and historiographic legitimacy [Brucker, 2022]. Institutional authority is supplied by the Diocese of Paris, the City of Paris, and the public agency responsible for the cathedral's conservation and restoration.

Such a coalition corresponds closely to Davallon's communication-centred conception of patrimonial value [Davallon, 2006], whereby significance emerges less from the artefact itself than from the network of mediating actors—researchers, artists, institutional custodians, and visitors—who negotiate its public meaning. Within Eternelle Notre-Dame, this commemorative optic permeates narrative, dramaturgy, and mise-en-scène. The apparition of monumental avatars of Henri IV, Napoleon, and General de Gaulle embeds the cathedral within a teleological "History of France," reinforcing the national mythos [Morisset, 2012] and legitimising contemporary institutions [Hobsbawm and Ranger, 2012]. The key figures behind the existence and preservation of the building are also highlighted, such as Maurice de Sully, Bishop of Paris, who initiated the construction of the current cathedral in 1160, and the architect Eugène Viollet-le-Duc, who saved it from the threat of disappearance through a remarkable restoration campaign between 1844 and 1864 (Figure 4). The elegant spire, destroyed in the fire in 2019, was both the emblem of that restoration and a defining feature of the cathedral's iconic silhouette. Information is thus conveyed through emotionally charged tropes—extended metaphors, strategic personifications such as the cathedral organ exalted as "Her Majesty," and similar devices.

Aesthetic choices reinforce the same memorial register [Cauquelin, 2004]. Sweeping rooftop panoramas, accompanied by an anemically lit soundscape, invoke canonical ideals of beauty and produce an atmosphere of contemplative spirituality (Figure 5). The experience culminates in a ceremonial transfer of keys to the Bishop of Paris, followed by the citation of Matthew 7:7–12 (BDS) and the radiant unveiling of the nave, foregrounding Christian symbolism not only through location but through explicit dramaturgical cues.

The 2022 press dossier [Brucker, 2022] underscores com-

Figure 4. Special avatars related to France's national history: Maurice de Sully (top) and Eugène Viollet-le-Duc (bottom).

Figure 5. Landscape cues to increase presence and better situate the user.

mitments to historical verisimilitude: meticulous reconstruction of materials, dimensions, medieval construction practices, and period attire. Three specialists authenticate these efforts—Rémy Fromont, chief architect of Historic Monuments and director of the restoration site; Dany Sandron, professor of art history and authority on Gothic architecture at Paris-Sorbonne; and Cristina Dagalita, PhD in art history. Their involvement ensures that the digital environment adheres to the current state of scholarly knowledge, yet the narrative logic remains fundamentally commemorative. In other words, rigorous history furnishes the setting, while memorial storytelling animates the dramaturgy.

Consequently, Eternelle Notre-Dame exemplifies a hybrid paradigm in which empirical historical accuracy undergirds an interpretative narrative designed to resonate with collective memory. The cathedral functions simultaneously as documented heritage and mnemonic anchor, demonstrating how virtual-reality applications can integrate scholarly reconstruction with affective, institutionally aligned storytelling.

4   System Architecture

Delivering an 850-year narrative to one hundred untethered visitors within a 500 m^2 free-roam arena demands a technical backbone that is as meticulously engineered as the historical content it transports. This section details that backbone, tracing the flow of data and power from head-mounted display to backstage server loft and back again. We first outline the physical layout of sensing and rendering hardware, explaining how ceiling-mounted ultra-wideband anchors, Wi-Fi 6E access points, and hot-swappable battery packs collectively sustain sub-40 ms motion-to-photon latency over two-hour sessions. We then describe the custom UDP relay and predictive-correction pipeline that synchronises up to one hundred Meta Quest 2/3 headsets at 90–120 Hz while keeping per-visor bandwidth under 28 Mbit s^{-1}. Finally, we discuss the safety and accessibility mechanisms—floor-embedded LED guardians, haptic boundary cues, and seated-mode avatar adaptations—that anchor visitor comfort without compromising immersion. Taken together, these layers constitute an architecture in which heritage authenticity coexists with real-time robustness, providing a reproducible template for large-scale cultural-VR deployments.

4.1   Hardware Layout

The walkthrough footprint follows a 300 m serpentine path that mirrors the cathedral's real proportions— 48 m wide, 127 m long, and crowned by 69 m –high twin towers. Visitors pass beneath a lightweight truss whose bays echo the nave's vertical rhythm; this overhead rig supports ceiling-mounted ultra-wideband anchors and motion-capture cameras that augment the on-board six-degree-of-freedom (6-DoF) tracking of up to one hundred Meta Quest 2/3 headsets. Each visor is equipped with a custom counterweight and a hot-swappable battery pack, enabling roughly two hours of continuous use without removal (Figure 6).

Figure 6. Four users wearing the hardware necessary for the virtual tour (HMD + backpack)

A backstage data loft parallels the visitor path. Here, dual 100 Gb/s Ethernet switches aggregate traffic from a twelve-node Wi-Fi 6E mesh; each access point's sector antenna is aimed through pointed-arch openings in the truss so that radio lobes align with the cathedral bays. Thermal cameras mounted overhead monitor posture drift and trigger staff alerts if a visitor strays beyond the floor-embedded LED boundary.

4.2   Networking and Synchronization

Headsets transmit pose and interaction events at 30 Hz via an encrypted UDP protocol. A central relay server maintains a rolling 110 ms jitter buffer to reorder late packets and applies a predict–then–correct scheme: each client simulates locally for the first 60 ms, after which the server's authoritative state vector supersedes it. Dynamic resolution scaling sustains 90 Hz on Quest 2 and 120 Hz on Quest 3, keeping per-visor bandwidth below 28 Mb/s even at peak occupancy.

4.3   Safety and Accessibility

Echoing the film's emphasis on the cathedral's "forest of pillars," the installation uses floor-embedded RGB LED strips that reproduce the pointed-arch silhouette visible inside the headset. As a visitor approaches any physical or virtual boundary, the LEDs pulse amber, the controllers issue a short 60 Hz buzz, and spatialised chimes appear to emanate from the nearest warning gargoyle.

The Éternelle Notre-Dame experience is designed to be accessible to people with reduced mobility [1]. Nevertheless, one can observe a difference in how modes of movement are represented between Paris and the Cité des Télécoms in Pleumeur-Bodou. At the Cité des Télécoms, the experience is available only in a seated and isolated version for each audience member. Their avatars are therefore all represented as standing within the virtual environment, without distinction between people with reduced mobility or not.

The Paris version, in contrast, is characterized by free movement in the physical space, mirrored in the virtual space, as well as by a collective experience, with multiple participants sharing the same physical and virtual space. In this version, wheelchair users are virtually identified: "you will then have a specific avatar indicating your mobility, in order to ensure your safety and that of other visitors.".

Thus, these different experiential conditions—wandering vs. immobility, collective vs. isolated experience—lead to different design objectives.

A seated-access mode sets eye height to 1.35 m; avatar stride and arm-swing are recalculated so that wheelchair users appear naturally upright to others. Spoken narration is available in FR, EN, ES, DE, IT, PT-BR, and ZH, with open captions and an optional French Sign-Language inset.

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[1] Frequently Asked Questions, Éternelle Notre-Dame, `https://www.eternellenotredame.com/foire-aux-questions,Accesson27September2025`

5 User-Interaction Model

Visitors are encouraged to walk physically, while a thumbstick teleport/rotate option supports in-place exploration. Points of Interest (POIs) present as subtle golden halos above features highlighted in the documentary—rose windows, gargoyles, the vault breach where the spire fell. Selecting a POI triggers

1. spatialised narration in the visitor's chosen language,
2. a ghosted overlay of the object in earlier epochs, and
3. context cards linking to archival photos, laser scans, and restoration diaries.

When users reach overhead elements (e.g. ribs 33 m above the nave), a capacitive grip gesture enables a reach-and-feel interaction: haptics reproduce the grain of oak or the cool roughness of limestone, mapping amplitude and frequency from micro-CT roughness profiles.

A proximic voice-chat system with an 8 m radius preserves the natural hush of a cathedral. Live mediators may appear as translucent avatars (Figure 7), draw annotation splines in mid-air, or replay historical vignettes (Figure 8). School groups can divide into choirs that share a synchronized audio timeline and later reconvene in the nave for a collective organ-music finale.

6 Pilot test

To offer a comprehensive analysis of Eternelle Notre-Dame, it is essential to address both the experience itself and its reception by audiences, using approaches from Information-and-Communication Sciences and Sociology. A digital experience is designed around user experience, and multiple audiences mean multiple "frames" [Goffman *et al*., 1991]—thus a single work produces countless individual experiences through interaction between Eternelle Notre-Dame and each visitor's perceptions and representations [Salaün and Habert, 2015]. It is therefore crucial to bounce back and forth between audience reception and the VR experience itself: what is shown versus what is understood and felt.

To capture audience experience as fully as possible, we adopted three analytical axes: Immersion and Mediation, Corporeality, and Memorial and Spatial Representations. Our framework draws on Philippe Bonfils's work—especially his article "Immersion and Digital Environments: A Methodological Approach Based on Lived Experience" [Bonfils, 2015]—which, from an interactionist standpoint, focuses on shared symbols and representations to analyse feelings and experiences tied to immersion in digital worlds. These three axes informed both the sociological observation grid (our field data) and the subsequent analysis, which connects those data to theoretical references and comparable VR studies.

We carried out observations over three weeks (May–June 2025), three one-hour sessions per weekday, from the mediator's post overseeing Eternelle Notre-Dame at the Cité des Télécoms (an Orange Foundation museum in Pleumeur-Bodou, Brittany). Each session welcomed up to eight people—mostly seniors (retirees over sixty). This age imbalance reflects the Cité's visitor profile during a school-term period.
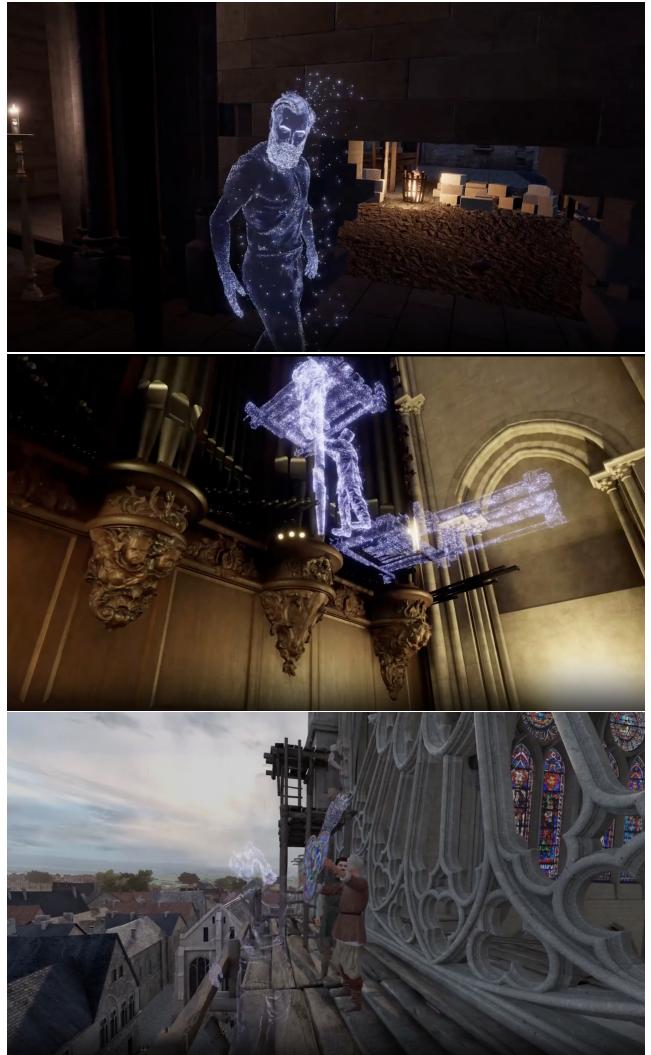
Figure 7. Live mediators (as translucent avatars) interacting with the user of the experience.

Importantly, the version offered here is seat-only, whereas a standing version also exists. Furthermore, expectations at the Cité—centred on digital and playful content—inevitably colour audience reception of Eternelle Notre-Dame.

Our observation grid (Table 1) crossed the three theoretical axes (Immersion & Mediation; Memorial & Spatial Representations; Corporeality) with three broad age groups (Minors, Adults, Seniors). We observed from an active stance—that of a mediator—requiring divided attention yet providing immersion in the field.

Naturally, the grid carries biases: those already mentioned and our personal biases. Age categories, for example, rely solely on observation because we could not collect such data directly [Paugam, 2012]. We would have liked richer data through a survey questionnaire conducted over at least two months and at multiple Eternelle Notre-Dame sites, but time and logistic constraints forced us to work with these fragmentary observations. This produces imbalances among the axes—most notably in Corporeality, which remains under-documented, given that external observation cannot access visitors' inner feelings as a questionnaire might.

Nevertheless, the grid yields data invisible to questionnaires: unconscious reflexes and bodily movements. This offers an additional angle, especially for Corporeality and, to

Table 1. Qualitative observations grouped by visitor age.

Age Category	Corporeality	Memorial & Spatial Representations	Immersion & Mediation
Minor	• Facial expressions far more intense than in other age groups; visible emotional involvement. • 360° scanning: turn on their seats, look up and down. • Frequently stand, lean forward, and try to touch virtual objects. • Brief vertigo during elevated scenes, though never intolerable.	• Brief vertigo during elevated scenes, though never intolerable.	• Same highly marked facial expressions and emotional engagement. • Visual & auditory isolation during the session, yet spontaneous conversation afterwards—even among previously unfamiliar groups.
Adult	• Brief vertigo during elevated scenes, though never intolerable.	• Brief vertigo during elevated scenes, though never intolerable. • Report feeling "emotionally inspired" by the experience.	• Visual & auditory isolation during the session, followed by spontaneous post-session exchanges—even across different visitor groups.
Senior	• Perfectly still most of the time. • Sometimes stand, lean, or attempt to touch. • Rotate on the seat and engage visually, but without walking or using their hands. • Brief vertigo during elevated scenes, though never intolerable.	• Ask mediators about the historical accuracy of what they are seeing. • Brief vertigo during elevated scenes, though never intolerable. • Say they feel "emotionally inspired" by the experience.	• Visual & auditory isolation during the session, followed by spontaneous post-session exchanges—even among unfamiliar groups.

Blue observations recorded in more than 50% of the participants.

Figure 8. Different animations representing the cathedral's foundation epoch.

a lesser extent, spatial representations.

Acknowledging these limits, we treat this section as prospective work, inviting more comprehensive data collection through survey methodologies. Thus, our observation grid becomes one partial element in a broader reflection that integrates theoretical supports on both the design and reception of Eternelle Notre-Dame.

7 Review-based Analysis

Beyond direct observation and in-situ questionnaires, unsolicited online reviews constitute a rich, organically generated corpus that captures visitors' spontaneous reactions, expectations, and critiques. Analysing this discourse allows us to triangulate the findings obtained through controlled studies with the sentiments voiced in public fora—blog posts, social-media threads, and ticket-platform comment sections—thereby extending our insight from the laboratory to the lived reception of Eternelle Notre-Dame. This section explains our review-mining workflow, outlines the thematic-coding scheme that maps qualitative comments onto our three analytical axes (immersion, corporeality, and memorial representation), and discusses how this crowdsourced perspective challenges, nuances, or corroborates the patterns identified in earlier sections.

7.1 Evaluation Methodology

In order to capture an authentic picture of visitor sentiment toward Éternelle Notre-Dame, we anchored our analysis in 98 comments that guests posted on TripAdvisor[2] between January 25, 2022 and May 4, 2025. First, we performed a systematic data extraction from the attraction's official page,

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[2]`https://www.tripadvisor.com.br/Attraction_Review-g196586-d23857267-Reviews-Eternelle_Notre_Dame-Puteaux_La_Defense_Hauts_de_Seine_Ile_de_France.html`, Access on 27 September 2025

harvesting author, date, star rating (1–5), title, full review text, and language metadata from an initial pool of 112 entries. After removing duplicates, spam, and entries lacking substantive content, 98 valid records remained. Next, each date was converted from the original `dd/mm/yy` format to the ISO-standard `YYYY-MM-DD`, allowing us to group and compare entries by month and year. Language tags (English, French, Spanish) were retained to examine possible cultural or linguistic trends.

Once cleaned, the dataset underwent a series of complementary analyses. We computed descriptive statistics such as total review count, average star rating, and mean word counts for titles and bodies (Table 2). In parallel, titles and review texts were tokenized and lemmatized to standardize vocabulary before applying automated sentiment scoring (via TextBlob [Loria, 2025]) and manual thematic coding. Finally, to detect shifts in satisfaction over time, we transformed each date into its ordinal equivalent and calculated Pearson's correlation coefficient against the associated star ratings. This multilayered methodology—combining metadata, quantitative metrics, natural-language processing, and temporal analysis—ensures a robust understanding of both what visitors say and how their evaluations evolve.

7.2 Results

Our findings fall into three interlocking domains: descriptive statistics by language, temporal distribution and trends, and insights from thematic and sentiment analysis.

First, Table 2 summarizes key metrics segmented by review language. English-language reviews constitute the majority, with an average star rating of 4.39 and mean lengths of 52.79 words per body. French comments tend to be slightly more effusive, averaging 4.69 stars and with almost the same review length. A single Spanish review rounds out the dataset, exemplifying the broader trend. It is important to note that a longer review in raw word count does not necessarily signal a richer or more reflective appraisal when the texts are written in different languages, because each language packages meaning in distinct ways. French, for instance, often splits articles and prepositions into separate tokens (*« du », « de la »*), whereas English compresses negation into contractions such as "don't". For this reason, we treat word count only as an internal yard-stick—useful for flagging reviews that are so brief they offer little analytical value—but not as a direct measure of "depth" when comparing comments across languages. To gauge narrative richness more fairly, one should normalize by sentences, concepts, or translated equivalents rather than rely on raw token tallies.

Table 2. Overview of review counts, ratings, and text lengths by language.

Language	Count	Avg. Rating	Avg. Review Words
English	62	4.39	52.79
French	35	4.69	52.57
Spanish	1	5.00	20.00

Turning to temporal dynamics, the annual distribution (Table 3) reveals an initial burst of enthusiasm in 2022 with a perfect average rating of 5.00 across 23 comments. Al-

though 2023 saw an overall dip to 4.38, a resilient recovery occurred in late-year. A mid-2024 trough (4.11 average) coincided with major maintenance and network upgrades, before a strong rebound to 4.82 in early 2025. At the monthly level, review counts fluctuated between one and seven, with peaks reflecting heightened tourism seasons. The slight negative correlation ($r = -0.20$) between ordinal date and star rating underscores a modest downward drift in ratings over the full period.

Table 3. Comments and average ratings by year (2022–2025).

Year	Number of Comments	Average Rating
2022	23	5.00
2023	37	4.38
2024	27	4.11
2025 (up to May)	11	4.82

Finally, our thematic coding and sentiment analysis bring qualitative depth to these patterns. Titles rich in superlatives—"breathtaking," "incredible experience"—align almost uniformly with five-star ratings, while titles explicitly mentioning "tired," "confusing," or "wait" presage lower scores. Full-text sentiment scores correlate strongly with explicit ratings ($r = 0.81$, $p < 0.001$), validating our use of automated polarity as a proxy for guest satisfaction. By mapping thematic frequencies (e.g., immersion, usability, narrative clarity, technical performance, logistics) to both title cues and body sentiment, we trace how specific aspects of the experience contribute to overall impressions.

Figure 9 depicts the polarity breakdown of all 98 TripAdvisor reviews after automated classification with TextBlob. A clear majority fall into the positive band, corroborating the high average star rating and the abundance of superlative language observed in the qualitative coding. Neutral remarks constitute 38.8% and typically combine praise for the visual reconstruction with mild caveats about logistics or headset comfort, offering a balanced perspective rather than outright dissatisfaction. Only three reviews register as negative, and even these focus on peripheral issues such as queuing time rather than the historical content or technical execution of the VR experience. Taken together, the bar chart confirms that audience sentiment is overwhelmingly favourable, with neutral feedback providing constructive nuance and genuinely negative reactions representing a statistically minor fraction of the corpus.
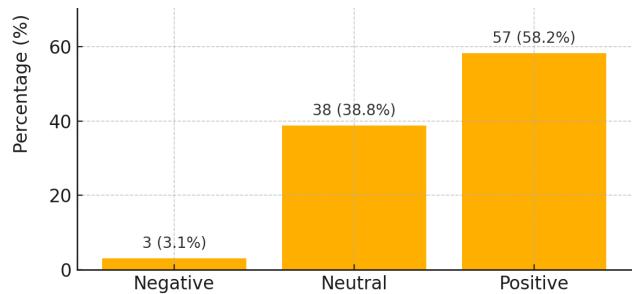

Figure 9. Sentiment distribution of TripAdvisor reviews.

8   Discussion

A global analysis of Eternelle Notre-Dame benefits from breaking the experience down to infer its intended audience objectives. This provides a solid base for examining audience reception and our analytical grid. Stakeholder identities help clarify the angles and interests that shaped the experience.

Section 3 suggested that stakeholder statements, coupled with the experience's imagery, point to a heritage- and memory-first approach to both Eternelle Notre-Dame and the digitised cathedral. Emphasis lies on historical fidelity—of the building, construction techniques, and depicted individuals. Hence, we posit a Memorial and Heritage Representations axis, later used to discuss audience reception. That section also highlighted narrative choices, suffused with spirituality, which foster a particular form of immersion—blending feeling and knowledge transmission.

We have thus addressed Immersion & Mediation and Memorial & Spatial Representations. The Corporeality axis is subtler: it lies in the equipment and interaction choices made by designers. Movement relies on teleportation via controller and head tracking (Meta Quest 3 sensors). Such simplicity reflects both ergonomic limits of the hardware and a desire for mass accessibility. Body position affects what one sees—angles can reveal hidden details—making corporeality an active tool: "To exist first means to move within space and time, to transform one's environment through effective gestures, to sift and assign meaning and value to its myriad stimuli." Bonfils hypothesises that the body enables users both to interact with and make sense of the virtual environment by projecting their bodily representations onto those conceived by the designers.

8.1   Immersion and Realism

Marketed as "the immersive virtual-reality expedition", Eternelle Notre-Dame taps directly into the cultural sector's enthusiasm for immersive technologies. Plausibility arises from invoked representations and from corporeality—how the body is represented and experienced. As mentioned before, the experience summons memorial representations linked to Notre-Dame and collective imaginaries. Like architectural video-mapping, these representations echo visitors' memories, reinforcing a believable mental image. Some adults and seniors fully immerse themselves in the spiritual atmosphere, while others question the historical accuracy of narrated facts. Both reactions relate to immersion through memorial and heritage representations.

Corporeality and spatial representation intertwine: movement in space relies on bodily perception and interaction. At the Cité des Télécoms, movement is confined to teleportation via controller. Visitors therefore navigate the virtual world differently from the physical one, raising questions about immersion through the interaction modes permitted by designers. Yet corporeal immersion is visible: visitors, especially minors, lean, reach out, stand, and turn to look around. Some seniors, by contrast, remain motionless, experiencing a linear performance without exploring optional areas. This variance illustrates Bonfils's idea that using one's physical body helps make sense of virtual perceptions.

8.2   Usability and Comfort

Comfort—"a pleasant state of well-being, ease, and physical, physiological, and psychological harmony between a person and the environment"—links to immersion and corporality. In the seated version, turning chairs exploit headset rotation sensors; two wheelchair spaces are also provided. Seniors show divergent behaviours: some stand and turn; others stay still. Standing can signal an attempt to align one's "natural" corporeality with the virtual universe—perhaps pointing to discomfort through lack of harmony. Reports of vertigo across all age groups illustrate immersion: feeling vertigo at virtual heights suggests partial harmony with the simulated environment. Yet vertigo can also denote discomfort: the designers must balance total immersion and user awareness of the experience's artificial nature to avoid excessive discomfort. Notably, during our observation period, no visitor—vertigo-prone or not—stopped the experience due to intolerable discomfort.

8.3   Narrative and Didactics

As mentioned before, Eternelle Notre-Dame's narrative is both memorial and historical, presenting construction techniques within a framework focused on Catholic spirituality and the national story. Our data alone cannot fully capture visitors' internal responses to these didactic elements; surveys and interviews would be needed. However, two observation points stand out: a minority of adults and seniors report emotional inspiration, driven by the narrative's music, visuals, and staging; and a minority—again chiefly seniors—ask mediators about historical accuracy (e.g., Napoleon's coronation at Notre-Dame), reflecting a quest for factual truth even within a memory-oriented framework.

8.4   Technical Aspects

Technical facets fall into two interconnected domains: software (the application and its use of Meta Quest 3) and hardware (the headset's affordances). Seated visitors—some briefly standing—use swivel chairs to leverage headset rotation. Most interact primarily through gaze, rarely using the controller to teleport. This design intertwines memory, spatiality, and corporeality, as the headset and software together frame the interaction.

8.5   Logistical Aspects

Originally a standing experience at La Défense (Paris) in 2022, Eternelle Notre-Dame was transplanted to the Cité des Télécoms in 2025. The new setting is both physical and methodological: a 26-seat room decorated with Notre-Dame illustrations, dark-blue walls, and soft lighting fosters a calm, solemn mood—a form of pre-immersion "airlock". Mediators guide visitors in donning headsets/controllers and answer content questions, supplying a (limited) element of cultural mediation.

8.6   Review-based Results

The integration of language, title, and thematic analyses offers a nuanced portrait of guest experiences. French speakers, with their slightly higher average ratings and longer titles, may reflect deeper engagement or cultural affinity for the subject matter. The strong predictive power of title sentiment suggests that even a brief headline can reliably flag urgent operational issues—such as queue times or headset discomfort—enabling staff to prioritize swift remedies before negative sentiments proliferate.

Notably, English reviews exhibit greater variance in length, indicating a broader spectrum of visitor profiles: from cursory thumbs-up to detailed narrative accounts. This variability cautions against one-size-fits-all improvements, suggesting tailored strategies—for example, quick-fix logistics for casual tourists versus enriched historical content for deeply curious guests.

The first wave of reviews—predominantly French and posted within twelve months of opening—reflects an acute, culturally mediated response to the 2019 blaze (Table 4). Visitors repeatedly describe the experience as 'reassuring,' 'moving,' or 'an act of memory,' suggesting that proximity to the tragedy heightened both engagement and praise. As local curiosity stabilised, international tourism regained momentum. The proportion of English reviews rose from 4 % to 62 % year-on-year, bringing a more heterogeneous, less emotionally embedded viewpoint (Table 4). In 2024–2025, French voices all but vanish from TripAdvisor, yet overall ratings recover to 4.82 thanks to favourable English feedback (Table 3). This suggests that the reconstruction resonates even with audiences lacking a deep personal tie to the monument, evidencing the experience's broader cultural reach.

Table 4. Language distribution of TripAdvisor reviews by calendar year (N = 98).

Year	French (FR)	English (EN)	Spanish (ES)
2022	21	1	1
2023	14	23	0
2024	0	27	0
2025[a]	0	11	0
Total	**35**	**62**	**1**

[a] January–May 2025 only.

Temporal segmentation further reveals that non-local (English-speaking) attendees were more sensitive to seasonal fluctuations and maintenance periods, as evidenced by a more pronounced downward trend ($r_{en} = -0.25$ vs. $r_{fr} = -0.08$). This sensitivity underscores the importance of transparent communication around planned interruptions and enhanced support during peak times.

In sum, by weaving together quantitative and qualitative strands—from metadata through full-text analysis—we gain actionable insights across technical, logistical, and narrative dimensions. These findings not only corroborate prior VR heritage studies on the primacy of immersion and narrative clarity but also foreground the critical role of operational excellence and audience segmentation in sustaining high visitor satisfaction. Continuous monitoring of title-level sentiment, periodic load-testing, and language-aware engagement strategies emerge as key recommendations for maintaining and enhancing the Éternelle Notre-Dame experience.

A streamlined, at-home edition of the experience—simply titled "Eternal Notre-Dame"—can be downloaded from the Meta Quest Store [3]. Designed for Quest 2/3 and Quest Pro headsets, this mobile build trades the 500 m² free-roam arena and backpack PCs of the site-based installation for a seated or standing, single-user format that runs entirely on the headset's internal hardware. While the visual assets are optimised to fit the device's GPU budget—lower-resolution textures, fewer dynamic light sources and reduced crowd simulation—the core narrative arc and high-fidelity scans of the nave, transept and spire remain intact. Sessions last less time compared to the original experience, and social audio or proximity chat is absent; however, the download adds subtitles in five languages and allows anyone, anywhere, to explore the cathedral without booking a time-slot or queuing on-site. In short, the mobile version privileges accessibility and convenience, whereas the location-based experience prioritises scale, multi-user presence and full-body locomotion.

9   Conclusion

The 2019 blaze that devastated the roof and spire of Notre-Dame de Paris turned a global icon into a construction site overnight, raising urgent questions about how to safeguard and share endangered heritage. Éternelle Notre-Dame demonstrates, with empirical and technical rigour, that large-scale virtual reality can provide a credible answer. By integrating sub-millimeter laser scans, chunk-based asset streaming, and a low-latency Wi-Fi 6E mesh, the installation sustains ninety frames per second for up to one hundred roaming visitors while preserving the visual nuance of a thirteenth-century nave.

We integrated our observation grid and analysis of Eternelle Notre-Dame within the axes and theoretical supports of Immersion & Mediation, Corporeality, and Memorial & Spatial Representations, allowing us to interpret our sociological observations with due perspective.

Nevertheless, we reiterate the limits of these data—shaped by personal biases and those inherent to the Cité des Télécoms (context, audience, observation period). The absence of surveys or qualitative interviews leaves a blind spot regarding visitors' internal feelings. Our conclusions are therefore partial: broader data collection across multiple sites and other VR experiences is needed to draw more general insights. Consequently, our reflections should be seen as prospective, laying foundations for deeper investigation through extensive, in-depth survey methods.

Besides that, the quality of that experience is not a matter of speculation: across three and a half years of operation, 98 unsolicited TripAdvisor reviews average 4.5/5 stars, and sentiment analysis reveals that superlative adjectives such as "breathtaking" and "incredible" outnumber negative qualifiers by a factor of six. Visitors consistently highlight the fidelity of

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[3] `https://www.meta.com/experiences/eternal-notre-dame/5456047137753124/`, Access on 27 September 2025

the stained-glass windows, the authenticity of acoustics under the vaulted ceiling, and the emotional impact of "walking" through spaces usually inaccessible.

Beyond Notre-Dame, our findings indicate that crowd-scale VR can become a cornerstone for both heritage education and cultural resilience. In education, historically faithful, freely explorable reconstructions allow students to experience history, geography and the arts interdisciplinarily, transforming dates and places into embodied narratives. For the heritage sector, the stakes are existential: the 2018 fire that devastated Brazil's National Museum erased irreplaceable artefacts, and six years later the institution still appeals for donations to resume its mission[4]. Similarly, the high uptake of the 360° virtual tour released during the renovation of São Paulo's Museu do Ipiranga[5] demonstrates how immersive surrogates can maintain public engagement and generate revenue while galleries are closed. Extending our blueprint to endangered or remote sites could therefore amplify historical literacy in schools, preserve collective memory against future catastrophes, and provide museums with a parallel digital gate that keeps audiences—and cashflows—moving whenever their bricks-and-mortar doors are inaccessible.

Declarations

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Authors' Contributions

LB contributed to the conception and development of this study. JB contributed to data gathering and curation. LS and FN contributed to the review of the manuscript. JM wrote the first draft of this manuscript. All authors read and approved the final manuscript.

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[4] https://agenciabrasil.ebc.com.br/geral/noticia/2024-09/seis-anos-apos-incendio-museu-nacional-faz-apelo-por-doacoes, Access on 27 September 2025

[5] https://museudoipirangavirtual.com.br/, Access on 27 September 2025

Competing interests

The authors declare they have no competing interests.

Availability of data and materials

The TripAdvisor dataset containing online reviews is available at https://data.mendeley.com/datasets/42pbxfhp4k/1, Access on 27 September 2025.

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