

Digital Innovation in Italian Museums: Visitor Experiences with AR/VR across Regional Contexts

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Abstract. This paper examines the adoption of immersive technologies – Augmented Reality (AR) and Virtual Reality (VR) – in Italian museums, focusing on how digital tools shape visitor experiences across different regional contexts. Building on earlier exploratory work conducted through online surveys and preliminary field research in winter 2024–25, the study draws on survey data collected in September 2025 from visitors across museums located in diverse territorial and institutional settings. The analysis combines descriptive statistics, regression models, and Structural Equation Modelling (SEM) to investigate the relationships between immersive technologies, visitor satisfaction, emotional engagement, post-visit understanding, and future behavioural intentions. The findings indicate that AR/VR experiences are positively and consistently associated with visitor satisfaction, emotional engagement, and cognitive outcomes across the sampled institutions. Emotional engagement and post-visit understanding emerge as the strongest predictors of positive evaluations and future intentions, while pre-visit expectations and familiarity with immersive technologies play secondary but significant roles. The results also indicate territorial variation in the adoption and perceived quality of immersive technologies, with patterns varying across regional and institutional contexts. Rather than suggesting uniform patterns of digital transformation, the study highlights how immersive experiences are *associated with* specific regional and institutional conditions that warrant further investigation. By combining experiential and territorial perspectives, the paper contributes to current debates on digital transformation in cultural heritage and smart cultural tourism. The findings suggest that the perceived value of immersive technologies is associated not only with technological availability, but also with the quality of narrative design and the broader contextual conditions of each institution. Future research may extend this work through longitudinal approaches and simulation models exploring the diffusion of AR/VR under different policy and funding scenarios.

JEL classification: Z11, Z32, O33, R12, R58

Key words: immersive technologies, regional heterogeneity, cultural innovation, AR/VR, PNRR, museums, digital transformation, cultural policy

1 Introduction

Over the past decade, digital transformation has profoundly reshaped the cultural and creative sectors, redefining how individuals experience, interpret, and access heritage (Bakhshi, Throsby 2012, Palumbo 2023). Museums and cultural institutions, traditionally perceived as custodians of tangible artefacts, are increasingly evolving into hybrid spaces that integrate physical and virtual dimensions (Di Leo 2023, Bonacini 2024). The rapid adoption of immersive technologies – such as Augmented Reality (AR) and Virtual Reality (VR) – represents one of the most visible aspects of this transformation, blurring the boundaries between cultural experience, technological innovation, and regional development (Sacco 2012, Grossi et al. 2023).

While immersive tools promise to democratize access and enhance engagement, their implementation is deeply uneven across territories (Cellini et al. 2024). While regional innovation gaps are a defining feature of the European digital landscape (Capello, Lenzi 2024), the Italian case is particularly illustrative. Disparities in Italy reflect broader EU-wide trends where peripheral or lagging regions face challenges in digital literacy and institutional capacity. These dynamics are further shaped by the country's historically rooted North–South socio-economic divide, making Italy a useful contextual case for exploring how territorial heterogeneity intersects with digital adoption in cultural institutions. Italy therefore offers a contextually relevant case: longstanding territorial asymmetries in innovation capacity, infrastructure, and institutional resources – extensively documented in the regional economics literature (Tranos 2013, Mauro et al. 2023, Cellini et al. 2024, Capello, Lenzi 2024) – intersect with digital adoption in ways the present study can observe only indirectly, through variation in visitor evaluations across macro-areas. Yet, digital innovation in culture is not merely a technological issue – it is a spatial one (Tranos et al. 2021). The quality of immersive experiences offered by cultural institutions is likely conditioned by local contexts – including available resources, accumulated digital expertise, and institutional capacity – factors that the present study can observe only indirectly through variation in visitor evaluations across macro-areas. Hence, the diffusion of AR/VR in museums may provide insights into broader patterns of digital transition across territories (Tranos 2026). In addition, because the survey data capture visitor responses to implemented AR/VR technologies across diverse institutional and regional settings, the analysis examines how these technologies are associated with visitor satisfaction, emotional engagement, and learning outcomes.

This study investigates how Italian museums integrate immersive technologies and whether adoption patterns vary across regional contexts. It builds on emerging literature on digital disruptions of space, which conceptualizes digitalization as both an enabler of regional connectivity and a driver of new forms of spatial polarization (Kitchin 2014, Antonietti et al. 2025). Specifically, the paper addresses three research questions:

1. To what extent do immersive technologies (AR/VR) relate to visitor satisfaction, emotional engagement, and learning outcomes?
2. How does the presence and perceived quality of immersive technologies vary across museum types and regional contexts?
3. To what extent do territorial characteristics/regional contexts appear associated with differences in visitor evaluations?

The Italian case offers a fertile ground to explore these issues, given its strong cultural diversity and persistent territorial asymmetries. From metropolitan museums in the North to smaller archaeological sites in the South, the diffusion of immersive technologies appears geographically uneven – a pattern consistent with the broader literature on regional digital divides (Capello, Lenzi 2024, Cellini et al. 2024). The regional dimension is considered in exploratory terms, with attention to possible differences across territorial contexts.

Moreover, national policy initiatives such as the *Piano Nazionale di Ripresa e Resilienza (PNRR)* explicitly promote digitalization in cultural heritage as a strategic driver for regional development and tourism resilience. Understanding how these interventions

interact with institutional practices and visitor perceptions can thus provide valuable insights into the spatial dynamics of digital transformation.

By combining survey data collected across museums located in several Italian regions with an exploratory regional analysis, this paper contributes to the growing debate on the territorial dimension of digital innovation in cultural sectors. The findings suggest patterns of uneven diffusion and possible differences in visitor experience across regions. These observations raise questions about the conditions under which digital innovation in cultural institutions is most effective, with potential relevance for ongoing policy discussions around territorial cohesion and cultural investment. The paper is structured as follows. Section 2 reviews the emerging literature on digital transformation in cultural heritage and situates the Italian case within broader debates on regional inequalities. Section 3 outlines the methodological framework, while Section 4 presents empirical results followed by a discussion of key findings. Section 5 concludes by highlighting policy implications for cultural innovation and regional development and outlining directions for future research.

2 Literature Review

2.1 Digital Transformation of Cultural Heritage

Research on the digital transformation of cultural heritage increasingly emphasizes its territorial dimension. Studies on regional innovation gaps (Capello, Lenzi 2019) and digital geography (Tranos et al. 2014) highlight how uneven infrastructures and institutional capacities shape the geography of digital adoption. Within cultural policy, scholars have examined how digitalization reshapes participation and governance (Bonet, Négrier 2018), situating museums and cultural institutions as microcosms of broader inequalities. Recent work has reinforced these perspectives. For example, Carta, Straccamore (2025) analyze territorial inequalities between digital innovation and the labor market, showing how regional disparities in skills and enterprise capacity hinder balanced digital growth. These contributions confirm that digital innovation is deeply embedded in spatial contexts, with implications for both economic and cultural sectors.

Within this broader landscape, immersive technologies such as AR and VR have attracted growing attention for their potential to enhance visitor satisfaction, emotional engagement, and learning outcomes. Systematic reviews and meta-analytic studies show that immersive tools can significantly improve cognitive and affective responses, visitor engagement, and museum learning outcomes, although their effectiveness depends on usability, narrative integration, and contextual factors (Beck et al. 2019, Yung, Khoo-Lattimore 2019, Zhou et al. 2022). More recent studies further nuance this picture. Omran et al. (2024) provide a hybrid review of VR and AR applications in tourism, showing that immersive environments can strengthen experiential and behavioral engagement, while also underscoring that their effectiveness is contingent on design quality and contextual factors. Complementarily, Omran et al. (2025) identify specific attributes of AR/VR tourism applications that predict behavioral engagement, further illustrating that technological features and user experience jointly shape visitors' responses. de Lourdes Calisto, Sarkar (2024) emphasize the importance of aligning immersive features with curatorial objectives, showing that AR/VR can deepen understanding only when embedded in coherent storytelling. Recent empirical work shows that AR-based immersive experiences can enhance user engagement and perceived authenticity, which in turn shape visitors' satisfaction with cultural places (Dağ et al. 2024).

In the field of cultural tourism, immersive technologies have been shown to enhance visitor satisfaction and engagement, though their outcomes remain contested (Dogan, Kan 2020, Fricano et al. 2025). Smart Tourism Technology further reshapes visitor experiences, with satisfaction acting as a key mediator of destination loyalty (Abou-Shouk et al. 2024, Lemy et al. 2025). Italian case studies illustrate both opportunities and constraints: projects like *Hidden Florence* and the *Smart City Living Lab* in Syracuse demonstrate AR's potential, but also reveal sustainability challenges linked to funding shortages and limited technical capacity (Graziano, Privitera 2020, Nevola et al. 2022). However, existing studies are predominantly based on single case analyses or specific

institutional contexts, with limited comparative evidence across multiple museums and regions.

Despite this accumulation of evidence, the existing AR/VR literature in cultural heritage exhibits at least three systematic limitations that the present study seeks to address. First, the predominance of single-site or single-institution designs (Bekele et al. 2018, Tom Dieck, Jung 2018, Dağ et al. 2024) limits cross-contextual generalizability, as findings obtained in technologically advanced or well-resourced museums may not readily transfer to smaller or less-endowed institutions. Second, existing studies rarely account for the territorial and institutional contexts in which museums operate, treating visitor responses as largely independent from the regional environments that shape governance capacity, funding opportunities, and patterns of digital innovation (Bonet, Négrier 2018, Cellini et al. 2024, Capello, Lenzi 2024). Third, the relationship between immersive experience quality and visitor outcomes remains predominantly associational, with relatively few studies addressing the endogeneity of technology adoption or the contextual mechanisms underlying digital implementation (Beck et al. 2019, Omran et al. 2025, Kline 2023). The present study addresses the first two limitations through a multi-site, multi-region design encompassing 35 cultural institutions across 12 Italian regions, while explicitly recognizing the third as an inherent limitation of cross-sectional survey research.

2.2 Cultural Tourism in Italy

Cultural tourism is a cornerstone of Italy's tourism economy. Although urban tourism is often multi-motivated – combining cultural attractions with food, lifestyle, leisure, and social activities – the present study focuses specifically on cultural participation within museums and heritage institutions, where immersive technologies are associated with visitor experience, emotional engagement, and learning outcomes. To grasp its scale, in 2019, the last full year before the pandemic, this sector accounted for about two-thirds (61.8%) of all tourism presence in the country (Santoro et al. 2024). The evolution of this fundamental sector in the past decade can be divided into three distinct stages: the robust pre-pandemic growth, the abrupt disruption caused by the health crisis and the solid recovery that followed, culminating in new record highs.

Before the COVID-19 health crisis, cultural tourism in Italy was on a path of consistent growth. Tourism presence was concentrated in three main categories of destinations, each with a distinct weight in the national landscape:

- municipalities with multiple vocations, which include a strong cultural component combined with other attractions, such as “cultural and seaside” or “cultural and mountain” vocations, account for 34.3% of tourism presence;
- large cities, which are urban centers with a multidimensional and concentrated tourism offering, like Rome, Florence, Venice, etc., represent 19.7%;
- municipalities with an exclusively cultural vocation; that is, destinations focused primarily on historical, artistic, and landscape heritage, denote 7.8% of tourism presence.

According to Liberatore et al. (2025), between 2015 and 2019, the upward trend was clearly established, with large cities leading the sector's expansion. However, performance was not uniform, as major cultural destinations exceeded the national average, while municipalities with multiple vocations showed a more modest increase. The greatest growth was noted mainly in large cities (+21.7%) and municipalities with an exclusively cultural vocation (+13.7%). Although both segments comfortably outperformed Italy's overall tourism growth rate of 11.2%, municipalities with multiple vocations registered a slower-paced increase of 8.7%. This period of prosperity and continuous expansion would, however, be abruptly ceased by the global crisis that was about to unfold.

The year 2020 represented a sharp turning point, with an unprecedented collapse in tourism. Dependence on international flows and the nature of their tourism offering made large cities particularly vulnerable. Large cities suffered the most severe decline,

Table 1: Cultural Participation and Spending across regions in Italy

Region	Cultural Participation	Average Household Expenditure
North and Center	30-40%	€117.8-€122.8
South	15-20%	€58.7

with a 74.2% drop in tourism presence, which was drastically higher than the national average of -52.3%. Municipalities with multiple vocations, however, demonstrated a greater resilience, with a smaller decrease of 44.1%.

The year 2021 marked the beginning of a gradual recovery, with an average national increase of 38.7%. Large cities again led the growth (+49.8%), surpassing the national average by more than 11 percentage points. Other segments, such as lake tourism (+82.3%) and spa tourism (+65.8%), also saw strong momentum, indicating a temporary diversification in travel patterns. This first step was essential to consolidating the broader recovery of the following years (Liberatore et al. 2025).

In 2022, the recovery accelerated significantly. Large cities played the leading role, with an incredible single-year increase of 104.4%. However, the recovery remained incomplete across the sector. Despite this leap, large cities were still 21.0% below 2019 levels, as were municipalities with an exclusively cultural vocation (-5.4%) and those with multiple vocations (-3.7%).

The year 2023 marked a milestone, with tourism in Italy reaching record levels, surpassing pre-pandemic indicators with more than 134 million arrivals and 451 million overnight stays (Laratta 2024). Regarding cultural tourism, three key points stand out: large cities reached an 18.5% share of total tourism presence, approaching their 2019 peak of 19.7%, which confirms a strong upward trend and an almost complete recovery; municipalities with an exclusively cultural vocation sustained a remarkably stable market share of around 8.2%, showing constant demand throughout the entire period; and the strong return of international visitors (34.5%), which was a crucial driver and accounted for more than 50% of the overall tourism market, emphasizing its central role in the sector's economic recovery.

This tourism recovery coincided with a renewed interest by Italians themselves in cultural activities. In 2023, participation in cultural events outside the home increased by 12%, with notable increases in museum visits (+44%) and archaeological site visits (+43%), demonstrating a reinforced appreciation of national heritage in the post-pandemic period. However, this positive outlook masks a persistent challenge: deep regional disparities. Accessibility, investment and cultural participation remain geographically unbalanced, creating a divide between the North/Center and the South of the country, as represented in Table 1.

Although there is an overall positive trend, significant regional inequalities persisted in cultural participation and spending, with the North and Center reporting higher engagement in attending cultural events and higher household spending when compared to the South. Despite the sector's overall success, overcoming this geographical divide remains one of the main challenges for more balanced cultural and tourism development in Italy.

In short, the trajectory of Italian cultural tourism between 2015 and 2023 offers a clear view of its resilience and dynamism. From pre-pandemic expansion to record-breaking recovery, several essential lessons emerge: first, it becomes clear that cultural metropolises are the main engines of tourism growth and recovery in Italy, but their strong dependence on international markets also makes them the most vulnerable to global shocks, such as pandemics or economic crises; second, municipalities with an exclusively cultural vocation demonstrated remarkable stability, as their market share remained constant before, during, and after the crisis, suggesting a more solid tourism base that is less susceptible to extreme variations; third and last, we may conclude that the future success of Italian cultural tourism will not depend solely on increasing visitor numbers, as its long-term sustainability is directly linked to the country's ability to reduce the deep divide between the North/Center and the South, whose participation

and investment data suggest persistent regional imbalances that represent a continuing challenge for more balanced cultural development across the country (Liberatore et al. 2025).

While cultural tourism in Italy encompasses a wide range of motivations and activities, museum visitation represents a core component of cultural participation. In this context, understanding how visitors engage with cultural institutions – particularly through immersive and digital tools – becomes essential for interpreting broader tourism dynamics. This is especially relevant given the persistent territorial differences in cultural participation and access, which may also correspond to differences in how digital innovations are experienced across regions – a question this study explores in exploratory terms.

3 Methodology

3.1 Survey Design and Data Collection

This study builds upon an earlier phase of research on immersive technologies in Italian museums, whose preliminary findings were based on data collected during the 2024–25 winter season (Liberatore et al. 2025). The present work extends the dataset both geographically and temporally, encompassing a broader range of institutions and visitor experiences. While some of the museums included here were part of the initial analysis, additional sites have since been surveyed, allowing for a more robust assessment of regional dynamics and digital adoption patterns. The research combines quantitative survey data with the analytical framework developed for agent-based modeling (ABM) simulations of technology diffusion. Although the ABM component is not the focus of this article, the survey design aligns with that broader research agenda, ensuring data comparability across time and regions.

The survey instrument consists of two main sections:

1. a *socio-demographic section*, collecting information on gender, age, educational background, and country of origin;
2. an *evaluative section*, focused on the visitor’s one-time immersive experience with AR/VR or related technologies. Responses were recorded on a five-point Likert scale, ranging from 1 (*strongly disagree / per niente*) to 5 (*strongly agree / molto*), with 3 representing a neutral position.

Each respondent completes the survey immediately after the physical visit to the museum or cultural site. Participation is voluntary and anonymous, with optional support provided by museum staff. Visitors access the questionnaire via a bilingual (Italian/English) QR code displayed at the exit area of each site. While the survey structure and measurement scale remain consistent across all sites, minor adjustments were made to reflect the specific immersive features offered by each museum (e.g., whether both AR and VR experiences were available or only one). The full dataset includes responses from museums located across northern, central, southern, and insular Italy. The institutions differ substantially in size, typology, and degree of digitalization, which enables a comparative perspective on the regional diffusion of immersive innovation. Data collection was completed in September 2025, following an extended campaign launched in late November 2024.

3.1.1 Survey variables and construction of composite indices

The survey captures visitor evaluations across three dimensions of the immersive experience:

1. *Pre-visit expectations* – measuring curiosity and interest generated by digital previews (e.g., virtual tours).
2. *During-visit experience* – assessing how immersive tools (VR, AR, or hybrid installations) contribute to engagement, clarity of information, emotional connection, and cultural understanding.

3. *Post-visit reflections and intentions* – evaluating the perceived usefulness of immersive technologies after the visit and the willingness to use or recommend them in the future.

To facilitate the analysis, individual items were grouped into conceptually coherent constructs, following standard practice in visitor studies and technology-adoption research:

- *Familiarity*: Q1
- *Pre-visit expectations*: Q2
- *Satisfaction during the visit*: Q3–Q6
- *Emotional engagement*: Q7
- *Post-visit understanding*: Q8
- *Future intentions* (reuse/recommend): Q9–Q10

Each index was computed as the arithmetic mean of its constituent items, preserving the original 1–5 Likert scale. Internal consistency (Cronbach's α) was evaluated for multi-item constructs (Satisfaction During the Visit and Future Intentions): the composite indices are valid, and both multi-item constructs show excellent internal consistency. Cronbach's α for *Satisfaction During the Visit* (Q3–Q6) is 0.927, and for *Future Intentions* (Q9–Q10) is 0.902.

Museums serve as the primary unit of analysis, with mean scores aggregated at the institutional level to mitigate biases from unequal response counts across sites, while recognizing that institutions with small respondent counts should be interpreted cautiously. For territorial comparisons, results are grouped into four macro-areas – North, Center, South, and Islands – according to the museum's administrative region (see Figure 1). The colored regions represent those containing the cultural sites included in the analysis. By contrast, the grey regions were not examined. Specifically, Friuli Venezia Giulia, Veneto, Emilia-Romagna (North), Marche (Center), Molise, and Calabria (South) did not possess adequate immersive technologies as of late 2024.



Figure 1: Cultural Institutions by Italian Macro Areas

3.1.2 Sampling

The sampling strategy operated at two levels. At the institutional level, the initial frame comprised all Italian museums and cultural sites adopting immersive technologies (AR/VR), identified through systematic telephone and website contacts. The study began from an attempt to identify the population of Italian museums using immersive technologies. A few major museums declined to join the survey due to logistical constraints (e.g., concerns that distributing the questionnaire might slow visitor flows), resulting in the exclusion of certain high-volume sites. The final institutional sample consists of participating sites that agreed to administer the survey. It includes 35 cultural institutions, distributed across four macro areas: North, Center, South, and Islands. Overview of the sites is provided in Figure 2. The selection of museum sites was guided by the availability of active AR/VR implementation projects during the survey period. While major tourism hubs such as Tuscany represent significant benchmarks for traditional heritage management, the specific digital innovation clusters under study were more concentrated in the sampled regions. Conversely, regions such as Calabria were identified as relevant counterpoints where lower digital adoption rates – often linked to structural infrastructure gaps – provide a baseline for understanding the ‘digital divide’ in the cultural sector. Future iterations of this research aim to expand the institutional sample to include these regions, which would enable more comprehensive cross-regional comparisons and reduce the current concentration of observations in specific territories.

a) North

- Forte di Bard (Valle d’Aosta)
- Rodari Museum (Piedmont)
- PA Antiquarium, Monastero d’Astino, Basilica S. Maria Maggiore, Museo Certosa, MAN Lomellina, Palazzo Besta, Villa Romana, Grotte Catullo, PA Massi Cemmo, PA Incisioni Rupestri, MAN Valcamonica (Lombardy)
- Retico Museum, Lumen Museum, Palafitte Fiaavè, Palazzo Cles, SASS (Trentino-Alto Adige)

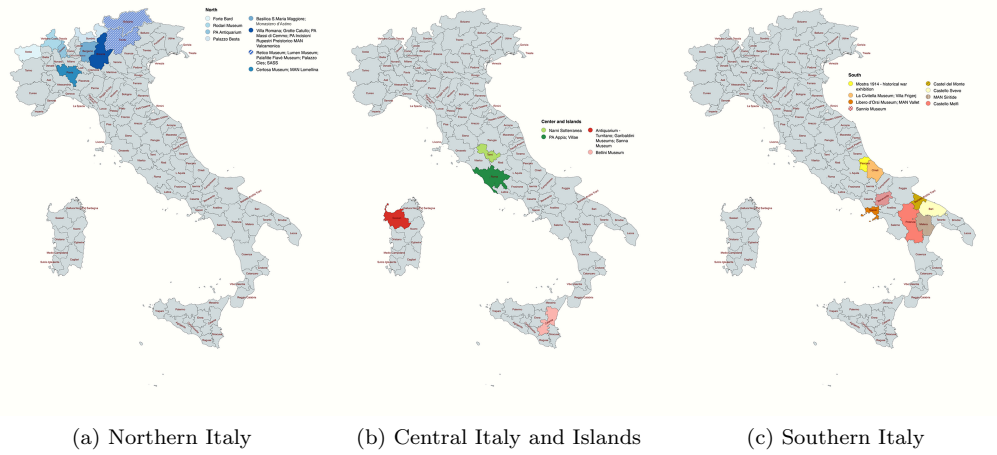
b) Center and Islands

- PA Appia, Villae (Lazio)
- Narni Sotterranea (Umbria)
- Garibaldini, Sanna, Antiquarium Turritano (Sardinia)
- Bellini (Sicily)

c) South

- MAN Villet, Libero d’Orsi, MAN Sannio (Campania)
- Castello Melfi, MAN Siritide (Basilicata)
- Castello Svevo, Castel del Monte (Apulia)
- La Civitella, Villa Frigerj, Mostra 1914 (Abruzzo)

Individual responses are used for behavioral models, whereas museum-level averages are used for descriptive institutional and territorial comparisons. At the visitor level, respondents were recruited on a voluntary basis immediately after their museum experience. As participation was self-selected and not pre-assigned, the visitor sample corresponds to a convenience sampling design (Lohr 2021). Because participation was voluntary both at the institutional and visitor level, the sample should be interpreted as geographically diverse but non-probabilistic. Consequently, findings are exploratory rather than nationally representative. While the study covers 35 cultural sites across 12 Italian regions, the distribution of respondents reflects a higher concentration in specific territories, particularly Sardinia and Campania. Rather than constituting a strictly weighted representative



Notes: Panel (a): institutions in Northern Italy (Valle d'Aosta, Piedmont, Lombardy, Trentino-Alto Adige). Panel (b): institutions in Central Italy (Umbria, Lazio) and the Islands (Sardinia, Sicily). Panel (c): institutions in Southern Italy (Abruzzo, Campania, Basilicata, Apulia). Highlighted provinces contain at least one surveyed site. Province boundaries follow ISTAT administrative divisions.

Figure 2: Location of Surveyed Cultural Institutions by Macro Area

census, the dataset provides a cross-regional exploratory perspective on how different institutional settings and local visitor profiles interact with immersive technologies. While this approach does not guarantee strict randomness, the large number of responses across diverse sites enhances the robustness of the dataset and allows exploratory comparisons across sites and macro-areas, while acknowledging unequal response distribution.

3.2 Analytical Strategy

To examine the correlates and experiential consequences of immersive experience quality, we estimate a set of statistical models based on individual survey responses. The modelling strategy addresses three analytical goals: (i) identifying the correlates of satisfaction during the immersive experience; (ii) examining the associations between immersive experience quality and emotional engagement and post-visit understanding; and (iii) evaluating how visitor experience constructs are associated with post-visit behavioral intentions.

3.2.1 Baseline Regression Model

As a first step, we estimate a regression model where satisfaction during the visit is explained by familiarity with immersive technologies, pre-visit expectations, socio-demographic controls (age, gender, education), and regional fixed effects:

$$\text{Satisfaction}_i = \beta_0 + \beta_1 \text{Familiarity}_i + \beta_2 \text{PreVisit}_i + \beta_3 \text{Age}_i + \beta_4 \text{Gender}_i + \beta_5 \text{Education}_i + \gamma_r + \varepsilon_i \quad (1)$$

where γ_r are regional fixed effects.

This model examines the associations between prior exposure to immersive tools and expectations, and the perceived quality of the experience. For robustness, we first estimate a preliminary specification including only continuous experiential predictors (Familiarity, Pre-Visit, Emotional, Post-Visit, Age), before introducing categorical controls and regional fixed effects. This step allows us to assess the stability of the core experiential drivers prior to accounting for demographic and territorial heterogeneity.

Institutional-level variation in AR/VR adoption across the 35 sampled sites is characterized descriptively through the spatial distribution shown in Figures 1 and 2. Formal modelling of institutional adoption is not pursued, as the sampling frame was defined

by active AR/VR implementation: all participating institutions had adopted immersive technologies prior to data collection, which precludes the use of adoption as a binary dependent variable.

3.2.2 Structural Equation Model

While the relationships among satisfaction, emotional engagement, post-visit understanding, and future intentions could be specified as separate regressions, we integrate them into a single Structural Equation Model (SEM) framework (Kline 2023). This approach allows for simultaneous estimation of direct and indirect effects, capturing the mediating role of emotions and learning outcomes. The SEM includes the following pathways:

- Familiarity and Pre-visit expectations → Satisfaction
- Satisfaction → Emotional engagement and Post-Visit understanding
- Emotional engagement and Post-Visit understanding → Future behavioral intentions

Control variables (age, gender, education, and regional fixed effects) are included in all endogenous equations. Estimation is performed using robust maximum likelihood with standardized coefficients, and model fit is assessed via CFI, RMSEA, and SRMR.

4 Results and discussion

4.1 Descriptive results

The dataset comprises 960 respondents distributed across 35 cultural sites located in northern, central, southern, and insular Italy. This broad coverage ensures that the analysis captures regional diversity and institutional heterogeneity in the implementation and visitor reception of immersive technologies.

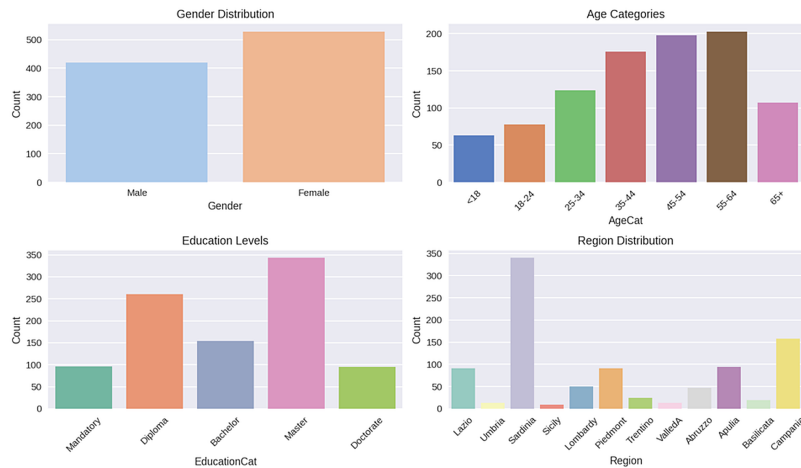


Figure 3: Demographic Distributions

Gender and Age. The sample is broadly balanced by gender (Figure 3). Female respondents are slightly more represented across all regions, with the Center showing the highest proportion of women. Age distributions reveal that middle-aged categories (35–54 years) dominate across all macro-areas, while the Islands display a relatively larger share of older respondents. Both genders are concentrated in the 35–54 range, although women are somewhat more represented in the younger categories.

Education. Education levels are relatively high overall, with strong representation of respondents holding Bachelor’s and Master’s degrees. Regional coverage is skewed toward

the Center and Islands, meaning that results may reflect those areas more strongly. The North exhibits a higher share of respondents with tertiary education, whereas the Islands lean more toward diploma or mandatory education levels (Figure 4).

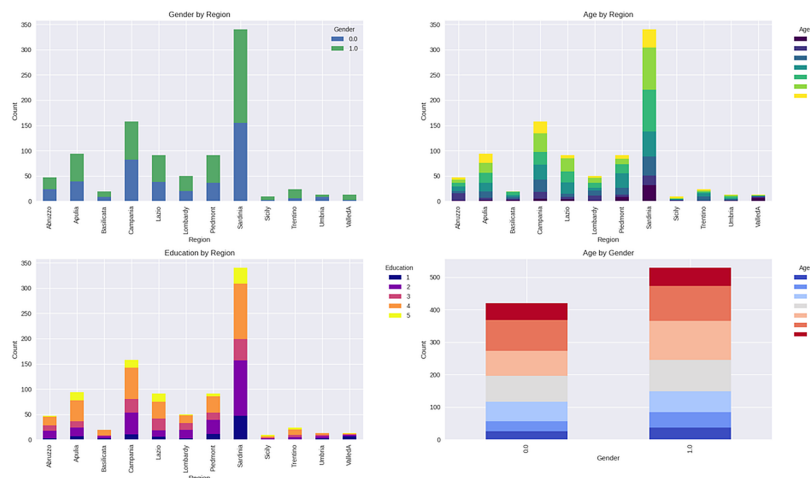


Figure 4: Demographic Cross Tabulations

Experiential indices. In Figure 5 we present the distributions of satisfaction, emotional engagement, familiarity, pre-visit expectations, and post-visit evaluations, together with cross-tabulations for satisfaction by region and emotional engagement by age group. Satisfaction and emotional engagement are consistently high across the sample. Familiarity and pre-visit expectations are moderate to high, aligning with strong post-visit scores. Regional patterns indicate that the Center and Islands tend to show higher satisfaction averages. Age differences are modest: younger adults (18–34) report slightly stronger emotional engagement, though middle-aged groups remain highly engaged. Figure 6 presents the correlation between each factor (Familiarity, Pre-Visit, Emotional, Post-Visit) and overall satisfaction at each sampled site. Emotional engagement and Post-Visit understanding show consistently positive correlations across most institutions. Familiarity and Pre-visit expectations show more variable patterns across sites. Results for institutions with small respondent counts should be interpreted with particular caution, as site-level correlations based on few observations are highly sensitive to individual responses.

Regional and institutional patterns. Comparative analysis across macro-areas highlights differences in visitor responses to immersive experiences across regional contexts. Museums in the North tend to attract visitors reporting higher technological familiarity, while institutions in the Center and Islands record higher average satisfaction scores. The mechanisms underlying this pattern are not directly identifiable from the present data; one possible interpretation is that greater prior familiarity with digital tools among northern visitors corresponds to higher evaluative standards, consistent with the negative association observed between education and satisfaction in the regression models.

4.2 Regression Analysis

The regression analysis proceeds in two stages. In the preliminary specification, only continuous experiential predictors are included – Familiarity, Pre-Visit expectations, Emotional engagement, Post-Visit understanding, and Age (Figure 7 a, b, c, d). This model exhibits strong explanatory power ($R^2 = 0.769$), with Emotional engagement and Post-Visit understanding emerging as the strongest associated factors of satisfaction. Pre-Visit expectations also contribute positively, while Familiarity and Age do not exert significant independent effects once experiential dynamics are controlled for. These results highlight that satisfaction is closely associated with the quality of the immersive experience itself,



Figure 5: Experience Variables: Distribution and Cross Tabulations

rather than by prior exposure or demographic characteristics. Diagnostic checks confirm the robustness of the specification: residuals approximate normality, heteroscedasticity is absent, and multicollinearity is not problematic (all VIFs < 5).

The residuals-versus-fitted plot shows no evidence of heteroscedasticity or nonlinearity, and the QQ plot indicates that residuals approximate normality, with only minor deviations at the tails. Cook's distance highlights a small number of potentially influential observations; however, none exert sufficient leverage to distort inference.

In the second step, categorical controls and regional fixed effects are introduced to account for demographic and territorial heterogeneity (Tables 2 and 3). The explanatory power decreases ($R^2 = 0.349$), reflecting the more parsimonious specification, yet the substantive hierarchy of effects remains consistent. Familiarity and Pre-Visit expectations continue to be significant positive correlates of satisfaction, while Education shows a negative association, suggesting that more highly educated visitors are slightly less satisfied – possibly due to higher critical standards. Age remains non-significant, and Gender is only marginally significant, with women reporting slightly higher satisfaction. Regional differences persist even after controlling for visitor characteristics: museums in the Center and Islands record higher satisfaction levels compared to the North. The specific mechanisms underlying this pattern – which may include institutional practices, visitor profile composition, or implementation quality – cannot be identified within the present design and warrant further investigation. The robustness of macro-area comparisons varies according to the regional distribution of respondents. The Center and Islands account for a relatively large share of the observations, whereas other regions are represented by considerably smaller samples. Consequently, regional differences should be interpreted as exploratory rather than statistically equivalent estimates. In particu-

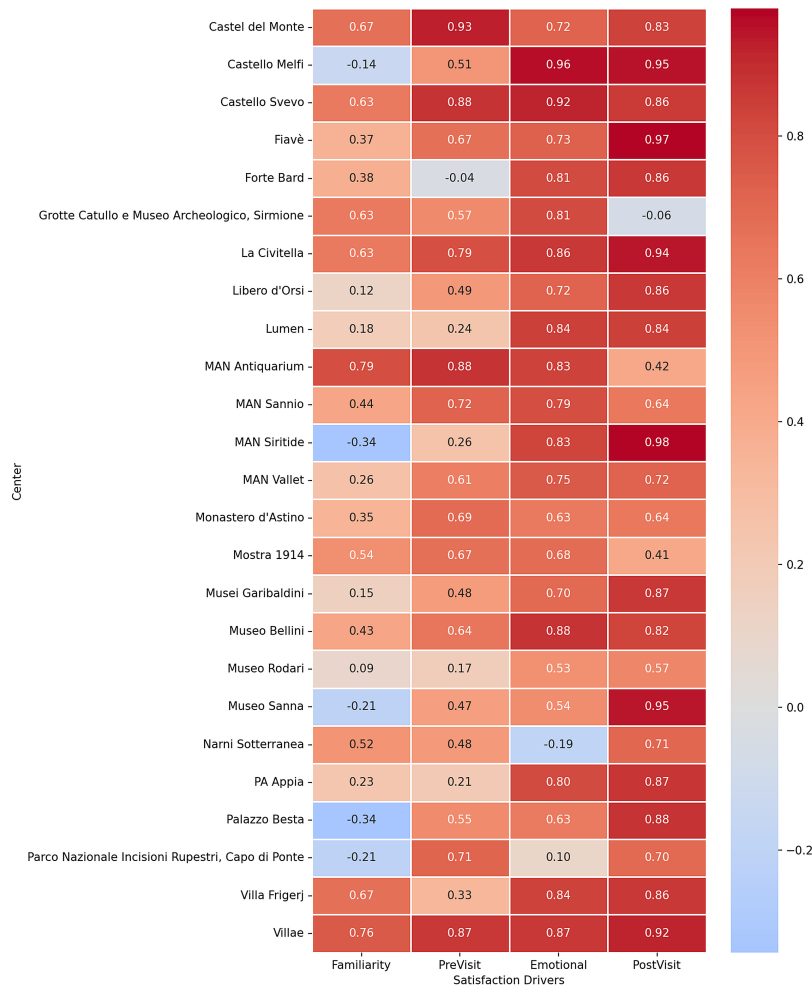


Figure 6: Correlations between Satisfaction Drivers and Total Satisfaction by Center

lar, the non-significant coefficient for the South (Table 3) may reflect limited statistical power as well as substantive similarity with the North reference category.

Overall, the regression results provide a coherent picture of the correlates of satisfaction with AR/VR experiences. Emotional engagement and cognitive consolidation during the visit show the strongest positive associations, pre-visit expectations contribute a secondary but consistent positive association, and regional context remains associated with satisfaction even after controlling for individual visitor characteristics.

Key correlates of satisfaction. The regression results highlight a clear hierarchy of effects. Emotional engagement and Post-Visit understanding show the strongest positive associations with overall satisfaction, consistent with the central role of affective resonance and cognitive consolidation in visitor evaluations. Pre-Visit expectations also show a consistent positive association, though of smaller magnitude. Familiarity with immersive technologies shows a positive association, though the magnitude is comparatively smaller. By contrast, education shows a negative association, suggesting that more highly educated visitors tend to be slightly more critical. Finally, the regional fixed effects reveal significant contextual differences, with museums in the Center and Islands reporting higher satisfaction levels than those in the North.

4.3 SEM results

Figure 8 presents the SEM tested to examine the visitor experience journey. The SEM integrates the relationships previously estimated in separate regressions into a single

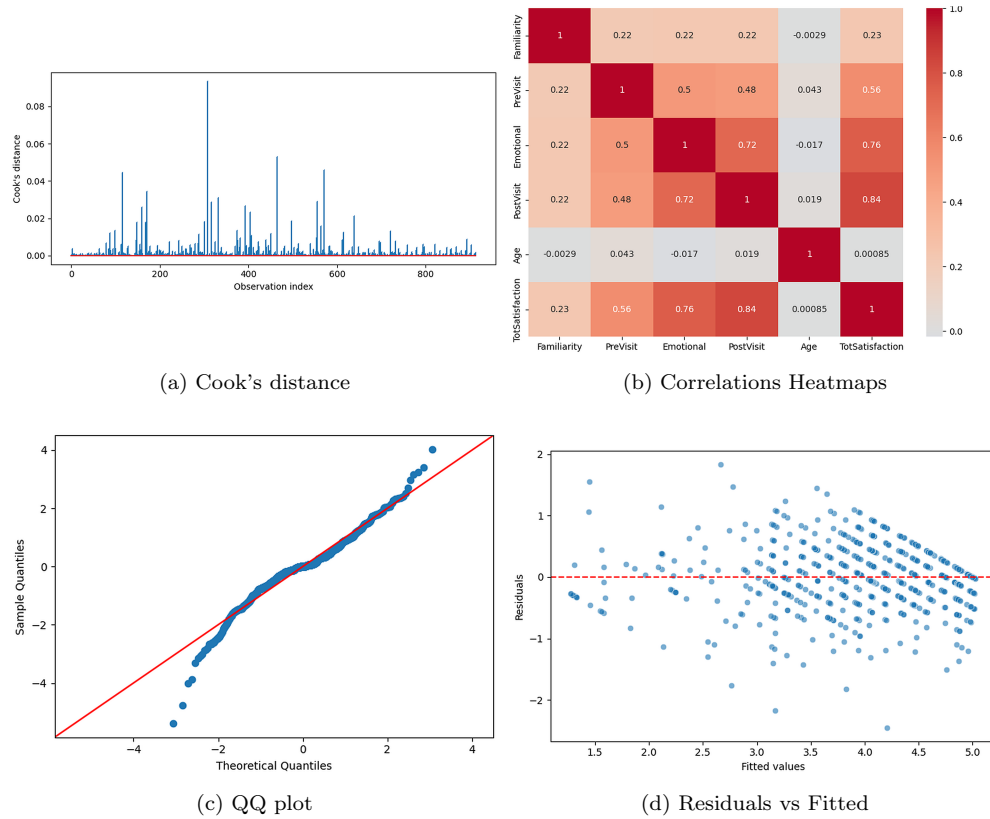


Figure 7: Statistical Analysis

framework, allowing for simultaneous estimation of direct and indirect associations within the structural model. The results are consistent with the hypothesized pathway linking pre-visit expectations, satisfaction during the visit, emotional engagement, post-visit understanding, and future behavioral intentions.

Both Pre-Visit expectations ($\beta = 0.42$, $p < 0.001$) and familiarity with immersive technologies ($\beta = 0.18$, $p < 0.001$) are significantly and positively associated with satisfaction during the visit. Satisfaction is strongly and positively associated with both emotional engagement ($\beta = 0.55$, $p < 0.001$) and Post-Visit understanding ($\beta = 0.49$, $p < 0.001$). These two constructs are in turn positively associated with future intentions, with emotional engagement ($\beta = 0.34$, $p < 0.001$) and post-visit understanding ($\beta = 0.31$, $p < 0.001$) showing comparable positive associations with visitors' willingness to reuse or recommend AR/VR technologies.

Control variables reveal more nuanced effects. Education shows modest negative associations with satisfaction and emotional engagement, suggesting that more highly educated visitors may apply stricter evaluative standards. Regional fixed effects indicate slightly higher satisfaction levels in the Center and Island regions compared to the North. The mechanisms underlying this pattern cannot be identified from the present data and represent a question for future research with matched institutional indicators.

Model fit indices confirm the robustness of the proposed pathway, with values well within conventional thresholds (CFI = 0.96, RMSEA = 0.04, SRMR = 0.05). These results indicate that the SEM provides a good fit to the data and is consistent with the proposed framework of visitor experience. Overall, the analysis highlights the central role of satisfaction as a mediating construct, associated with pre-visit expectations and familiarity on one side, and with emotional and cognitive outcomes on the other – outcomes that are in turn associated with future behavioral intentions.

The findings from the regression and SEM analyses are broadly convergent in terms

Table 2: Regression Summary

Model / Dependent Variable	Independent Variables	Coefficient (β)	Std. Error	R^2
Visitor Satisfaction	AR/VR Experience Index	+0.42	0.08	0.28
	Age, Education, Region	Controls	–	–
Emotional Engagement	AR/VR Experience Index	+0.37	0.07	0.25
	Age, Education, Region	Controls	–	–
Learning Outcomes (Post-Visit)	AR/VR Experience Index	+0.33	0.09	0.22
Perceived Impact (TotSatisfaction)	Familiarity	+0.29	0.06	0.31
	(Digital Literacy proxy)			
	Region (Center vs North)	+0.21	0.07	–
	Region (Island vs North)	+0.18	0.08	–

Note: Coefficients represent standardized associations estimated via OLS regression with robust standard errors. All models are estimated at the visitor level ($N = 960$). Given the cross-sectional, non-probabilistic design, estimates should be interpreted as descriptive associations rather than causal effects. Institutional-level variation in AR/VR adoption is characterized descriptively in Figures 1–2; formal institutional-level modelling is precluded by the sampling design (all 35 participating sites had active AR/VR installations at the time of data collection).

Table 3: Baseline Model

Variable	Coefficient (β)	Std. Error	p-value
Familiarity	+0.121	0.05	0.025**
Pre-Visit	+0.403	0.09	0.025**
Age	+0.012	0.02	0.445
Gender	+0.098	0.05	0.051
Education	-0.079	0.02	
Region FE (γ_r)	varies	–	–
Model fit: $R^2 = 0.349$			

Note: Regional fixed effects indicate higher satisfaction in Center and Islands relative to North (reference category); South shows no statistically significant difference from the reference in the full specification.

of the strength of associations among key variables, though the two frameworks differ in their structural logic. In the regression, emotional engagement and Post-Visit understanding are specified as correlates of satisfaction; in the SEM, satisfaction is positioned as an antecedent of both. These specifications are not contradictory: they reflect different analytical vantage points on the same experiential pathway. The regression isolates associations with satisfaction at a single outcome level, while the SEM models how satisfaction is associated both with antecedent expectations and with downstream experiential outcomes. Taken together, the two approaches provide convergent evidence that the quality of the immersive experience – rather than demographic characteristics or prior technological exposure – constitutes the primary correlate of visitor evaluations and future behavioral intentions. Regional differences identified in the regression are also reflected in the SEM fixed effects, confirming that macro-area context is associated with visitor evaluations even within the structural model.

4.4 Discussion

Across both the regression and SEM analyses, emotional engagement and Post-Visit understanding emerge as the central correlates of visitor satisfaction and future behavioral intentions. This finding is consistent with established frameworks in visitor studies, where the interplay between affective resonance and cognitive consolidation constitutes the primary driver of meaningful cultural experiences (Falk, Dierking 2016, Packer, Balantyne 2016). The comparatively weaker role of familiarity with immersive technologies is noteworthy: it suggests that prior digital exposure does not substantially condition the quality of the immersive encounter once in-visit dynamics are accounted for. This resonates with Trunfio et al. (2022a), who show that the effectiveness of AR/VR in heritage contexts depends more on the coherence of the narrative design than on visitors' tech-

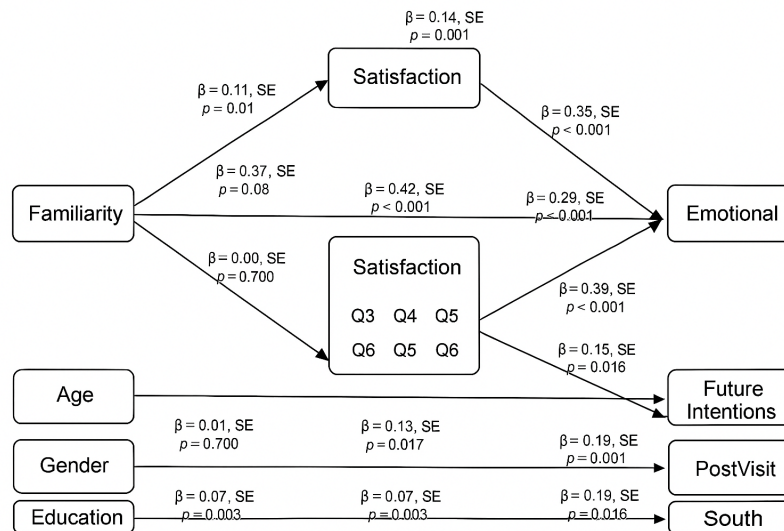


Figure 8: SEM path model showing standardized relationships among visitor experience constructs

nological background, and with [de Lourdes Calisto, Sarkar \(2024\)](#), who emphasize the primacy of curatorial alignment in predicting cognitive outcomes. The negative association between education and satisfaction, consistent across both models, echoes broader debates in museum pedagogy: more highly educated visitors may apply stricter interpretive frameworks, raising the threshold for perceived quality ([Hooper-Greenhill 2007](#)). For cultural institutions, this implies that investment in immersive technologies should be evaluated primarily in terms of narrative design, sensory integration, and interpretive depth, rather than technological specification alone.

Pre-visit expectations exert a consistent but secondary positive association with satisfaction, a pattern worth unpacking. Preparatory digital content – virtual tours, preview applications, online previews – appears to prime visitor curiosity and frame the immersive encounter, yet its contribution to overall satisfaction is substantially smaller than the in-visit and post-visit dynamics. This hierarchy is consistent with expectation-confirmation models in consumer research ([Oliver 1980](#)) adapted to heritage contexts ([Trunfo et al. 2022a](#)): initial expectations shape entry conditions, but sustained engagement and evaluative closure depend on the quality of the experience itself. The practical implication is that pre-visit digital investments are unlikely to substitute for in-gallery narrative quality, though they may lower the threshold of initial unfamiliarity, particularly for visitors with limited prior exposure to immersive environments.

The persistence of regional variation in visitor satisfaction, even after controlling for individual characteristics, points to macro-area context as a correlate of the immersive experience that visitor demographics alone do not capture. Museums in the Center and Islands record higher satisfaction levels compared to those in the North, a pattern that cannot be attributed to visitor composition alone. This finding should, however, be read alongside the sample's uneven geographic distribution: the Center and Islands are among the macro-areas with the highest concentration of respondents and surveyed sites, whilst the South – despite its cultural heritage significance – is represented by a more dispersed set of institutions with lower average visitor counts per site, which limits the direct comparability of macro-area estimates and counsels against treating the regional pattern as a balanced cross-national finding. Several interpretations are plausible: institutions in central and insular regions may benefit from a tighter alignment between heritage narrative and immersive technology, or from smaller visitor flows that allow more individualized engagement; alternatively, northern visitors' comparatively greater familiarity with digital tools may translate into higher evaluative standards, consistent with the negative association observed between education and satisfaction across both models. It is important to

note, however, that this exploratory dataset does not permit causal attribution of these differences to macro-level territorial inequalities. The sample is non-probabilistic with uneven regional distribution, and the analysis cannot disentangle institutional practices from local infrastructure conditions or visitor selection effects. The regional fixed effects capture residual variation across macro-areas but do not identify the specific mechanisms underlying that variation. The observed pattern is consistent with – but does not confirm – hypotheses drawn from the broader literature on Italy’s territorial asymmetries in innovation capacity and institutional quality (Felice 2019, Mauro et al. 2023, Cellini et al. 2024). Establishing such connections empirically would require matched institutional data, longitudinal design, or quasi-experimental identification, which represent natural extensions of this work.

The analytical strategy adopted in this study – cross-sectional survey data modelled through regression and SEM – is appropriate for identifying patterns of association among visitor experience constructs and for mapping structural pathways within the experiential journey. It is not designed to establish causal claims about the effects of immersive technology adoption on visitor outcomes, nor to isolate the independent contribution of territorial context from institutional practices or visitor selection effects. The SEM framework models concurrent associations under hypothesized directional constraints; while these constraints are theoretically motivated and empirically supported by model fit, they do not substitute for experimental or quasi-experimental identification (Kline 2023). Potential endogeneity – whereby the decision to adopt AR/VR may be systematically correlated with unobserved site-level characteristics such as institutional quality, funding history, or visitor profile composition – cannot be addressed within the present design. Future research incorporating instrumental variables, matched comparisons across institutions with and without immersive technologies, or Difference-in-Differences designs exploiting policy-driven adoption events (e.g., PNRR funding cycles) would substantially strengthen causal inference in this domain.

Situated within the regional economics literature, the observed macro-area pattern invites a further layer of interpretation. Cellini et al. (2024) demonstrate, for Italian museums specifically, that the quality of the regional institutional context – measured through governance indicators and public funding levels – is positively associated with museum service quality outcomes. The finding that visitor satisfaction is higher in the Center and Islands than in the North, even after controlling for visitor-level characteristics, may be read as a visitor-side expression of this supply-side institutional heterogeneity. The connection cannot be established directly without matched administrative data, but the convergence between the two bodies of evidence is suggestive. More broadly, the pattern is consistent with Capello and Lenzi’s (2024) account of heterogeneous regional responses to technological transformation: territories differ not only in their rates of digital adoption but in the quality of the institutional fabric through which technological investments are translated into outcomes. Mauro et al. (2023) further document how institutional endowments – social capital, governance quality, decentralisation patterns – mediate the relationship between investment and regional economic performance in the Italian context. Cultural institutions constitute one node of that fabric, and the visitor experience may be among its observable outputs – a hypothesis the present study can motivate, but not resolve, from cross-sectional survey data.

Taken together, the experiential and territorial dimensions examined in this study are not independent: the ability of immersive technologies to generate affective and cognitive value appears associated with how effectively institutions embed them in coherent narratives. The observed regional variation is consistent with – but does not directly measure – possible differences in institutional resources and implementation contexts across territories. This interdependence suggests that visitor experience research and regional innovation research speak to the same underlying phenomenon – the conditions under which digital tools create public value – even when approached through different analytical lenses. Addressing this intersection more directly, through designs that combine visitor-level survey data with institutional and administrative indicators, represents a productive direction for future inquiry (Trunfio et al. 2022b, Cellini et al. 2024).

The results suggest that in Italian museums, visitor satisfaction with immersive tech-

nologies is more strongly associated with the quality of the experiential encounter – particularly its emotional and cognitive dimensions – than with visitors’ prior technological familiarity or demographic background. Regional context shows residual associations with satisfaction that remain unexplained by visitor-level variables, pointing to an institutional and territorial layer of variation that warrants more direct empirical investigation. From a regional science perspective, this finding raises a specific and tractable question: whether the spatial pattern in visitor evaluations reflects underlying differences in regional institutional quality, public investment, or territorial knowledge spillovers – precisely the types of mechanisms that comparative regional methods are well equipped to examine (Cellini et al. 2024, Capello, Lenzi 2024, Antonietti et al. 2025). The present study contributes a visitor-side, multi-region empirical foothold for that inquiry.

5 Conclusions and limitations

This study offers one of the first multi-region visitor-based empirical assessments of AR/VR adoption in Italian museums. By integrating regression models and SEM across a geographically diverse sample, the study finds that AR/VR experiences are consistently associated with higher visitor satisfaction, emotional engagement, and post-visit understanding. Within this pattern, emotional engagement and post-visit understanding show the strongest associations with future behavioral intentions, suggesting that the experiential quality of the immersive encounter – rather than technological familiarity alone – is the key correlate of positive outcomes.

At the same time, the results suggest heterogeneous regional patterns. Museums located in the Center and Islands report higher satisfaction levels, while institutions in the North – despite greater technological familiarity – show comparatively weaker experiential outcomes. This pattern of regional heterogeneity may be viewed in the context of longstanding debates on the North–South divide in Italy, where structural differences in innovation capacity and institutional resources have been widely documented (Felice 2019, Mauro et al. 2023, Cellini et al. 2024). Whether the observed variation in visitor evaluations reflects these broader structural dynamics cannot be determined from the present data, and represents a question for future research. The results suggest that the perceived quality of immersive experiences varies across regional contexts in ways that cannot be fully explained by visitor-level characteristics. This regional heterogeneity is consistent with broader arguments in the literature about territorial variation in institutional resources and digital adoption capacity (Cellini et al. 2024, Capello, Lenzi 2024), though the present study is not designed to test those mechanisms directly. The finding contributes to exploratory evidence on how visitor experience quality may vary across territorial contexts in the Italian museum system.

The findings carry exploratory implications for cultural policy, to be read in light of the study’s non-probabilistic design. The observed association between regional context and visitor satisfaction suggests that the effectiveness of AR/VR investments may depend substantially on implementation conditions – including institutional capacity, narrative design, and visitor mediation – rather than on hardware availability alone. This is consistent with evidence from Italian case studies showing that sustainability challenges in digital heritage projects frequently relate to organizational and financial constraints rather than technological ones (Graziano, Privitera 2020, Nevola et al. 2022). If this pattern holds more broadly, policy programs such as the *Piano Nazionale di Ripresa e Resilienza* (PNRR) may produce more contextually effective outcomes by pairing infrastructure funding with investment in narrative design capacity and staff training, particularly for smaller and less-resourced institutions. Partnerships between technologically advanced institutions and those with more limited capacity could support knowledge transfer across regional contexts. These suggestions are indicative rather than prescriptive: they reflect patterns observed in an exploratory dataset and should be tested through more rigorous evaluation designs before informing resource allocation decisions.

Despite its geographic scope, the study is subject to several methodological constraints that should inform the interpretation of findings. First, data collection relied on anonymous, self-selected visitor responses administered via QR code at the exit of

each site. This design is efficient for large-scale deployment but introduces at least two forms of selection bias: visitors with limited digital literacy may have been less likely to complete a QR-based survey, and the voluntary, non-remunerated nature of participation may generate a volunteer bias whereby respondents systematically report more positive evaluations than the full visitor population. Both biases likely operate in the direction of upward satisfaction scores, and their magnitude cannot be estimated within the present design.

Second, the cross-sectional nature of the dataset precludes any assessment of longitudinal dynamics in AR/VR adoption or visitor experience, and – combined with the observational design – limits the ability to draw causal inferences. In particular, the decision to adopt immersive technologies is endogenous: institutions that invest in AR/VR may differ systematically from those that do not in ways that also affect visitor experience (institutional quality, funding access, governance capacity, visitor profile composition). The regional fixed effects included in the models partially absorb these confounders at the macro-area level, but cannot eliminate endogeneity at the institutional level.

Third, the distribution of respondents across sites is highly uneven, with Sardinia and Campania together accounting for a disproportionate share of observations. Institution-level correlation patterns (Figure 6) should be interpreted with particular caution for sites with fewer than approximately 20 respondents, as small-sample correlations are highly sensitive to individual responses and may not be stable across replication. Where possible, results from sites with low response counts have been noted as provisional; future iterations of this research should establish minimum site-level sample thresholds as a pre-registration criterion.

Fourth, the absence of matched administrative or financial data on the surveyed institutions prevents the analysis from directly assessing the role of institutional characteristics – budget, governance structure, staff size, prior digital investment – in shaping visitor outcomes. Linking survey data with institutional records would enable a more precise decomposition of the visitor-level and institution-level contributions to the observed patterns.

Building on these limitations, future work should employ longitudinal or panel data to track the evolution of AR/VR adoption over time. This study is situated within the broader framework of the PRIN (Progetti di Rilevante Interesse Nazionale) policy context, which promotes innovation and territorial cohesion in cultural sectors. While the present analysis provides a cross-sectional assessment of visitor experiences, the PRIN framework may offer opportunities for future longitudinal and policy-oriented evaluation. Future research could therefore explore quasi-experimental approaches, such as Difference-in-Differences (DiD) or Regression Discontinuity Designs (RDD), to assess the potential effects of digital funding interventions on museum performance, visitor engagement, and regional attractiveness.

Qualitative case studies could complement survey metrics by capturing institutional practices and visitor narratives in greater depth. Comparative analyses across countries would situate the Italian case within broader European and global trends. Finally, linking survey data with administrative and financial indicators, and developing agent-based simulations, will provide deeper insights into how institutional strategies and territorial contexts interact to shape the trajectory of digital innovation in cultural heritage.

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